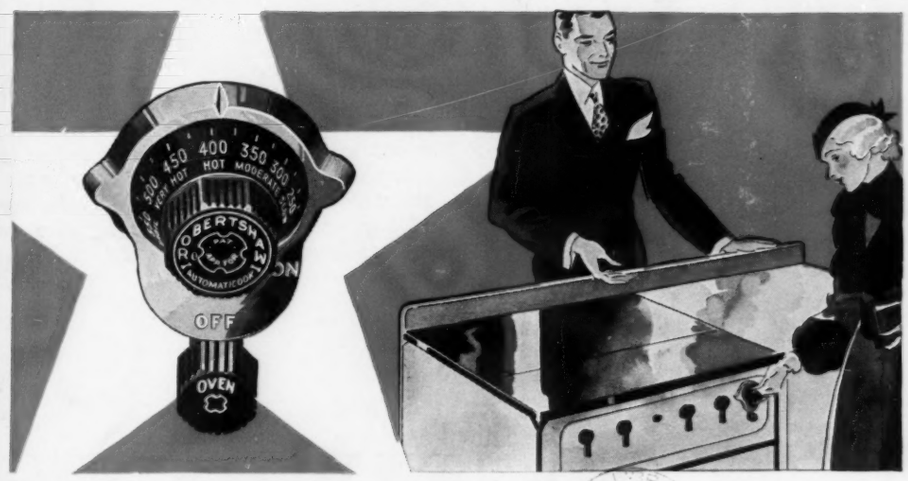
WESTERN GAS

ptember
1933

25 Cents
the Copy

YOUR STAR SALESMAN



SHOW the Robertshaw . . . and you have her interest immediately.

The records prove it. Over 1,800,000 Robertshaw equipped ranges are now in use. And every one of them is still doing a selling job . . . for the woman who has a Robertshaw is constantly telling her friends about it.

NEW

Model "FC" Combination Thermostat and Oven Valve. Both units—grouped together for convenience and attractive design—are entirely separate in operation and adjustment.

Women today, more than ever before, want the freedom of Robertshaw automatic oven control . . . the relief from kitchen drudgery . . . the certainty of trouble-free performance that is *only* assured by a *genuine* Robertshaw.

Your best selling plan this season is to push the ranges you have faith in . . . the Robertshaw equipped ranges that experience has proved will give continuous satisfaction and keep free from costly service charges.

ROBERTSHAW THERMOSTAT COMPANY • YOUNGWOOD, PA.

ROBERTSHAW

"AutomatiCook"

A MONTHLY JOURNAL DEVOTED TO THE WESTERN GAS & APPLIANCE INDUSTRIES

TECHNICAL EDITION

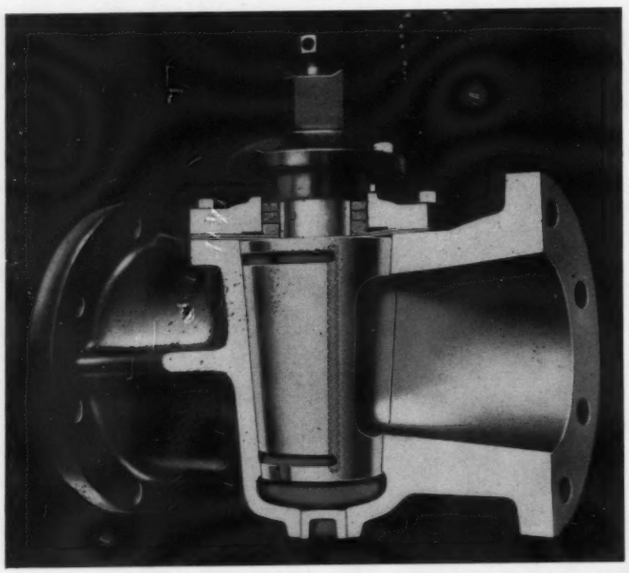
EMCO products...

- Emco Standard Domestic Meters
- Emco Curb Box Meters
- Emco High Pressure Meters
- Emco Balanced Valve Regulators
- Emco Service Regulators
- Emco Gas Appliance Regulators
- Emco Pressure and Vol. Recording Gauges
- Emco Liquefied Gas Regulators
- Emco Orifice Meters
- Emco-McGaughy Integrator
- Emcorector
- Calemco Regulators

Infallible gas measurement & control

Specializing in the manufacture of measurement and control equipment for gas, Pittsburgh Equitable Meter Company stands foremost in the Industry. Engineering and advisory service is offered by the company's offices located throughout the United States.

NORDSTROM VALVES...



—with patented "Sealdport" lubrication

Precedent was cast aside, in the early development of the Nordstrom design and in its manufacture. New engineering standards were conceived. The entire Nordstrom factory was designed, constructed and "tooled-up" for the exclusive production of lubricated plug valves. Years have been devoted to the development of special machinery to assure a thoroughly standardized design. Nordstrom Valves are more than valves. They reflect a service which is impossible to duplicate in any other plant. The fact that more Nordstrom Valves are operating in the Gas Industry than all other lubricated plug valves combined indicates their acceptance and success.

THE PERFECT APPLICATION OF A PRINCIPLE

•

Emco Products and Nordstrom Valves are a combination that have contributed immeasurably to the success of Gas Industry operations. May we supply Bulletins featuring the various products?

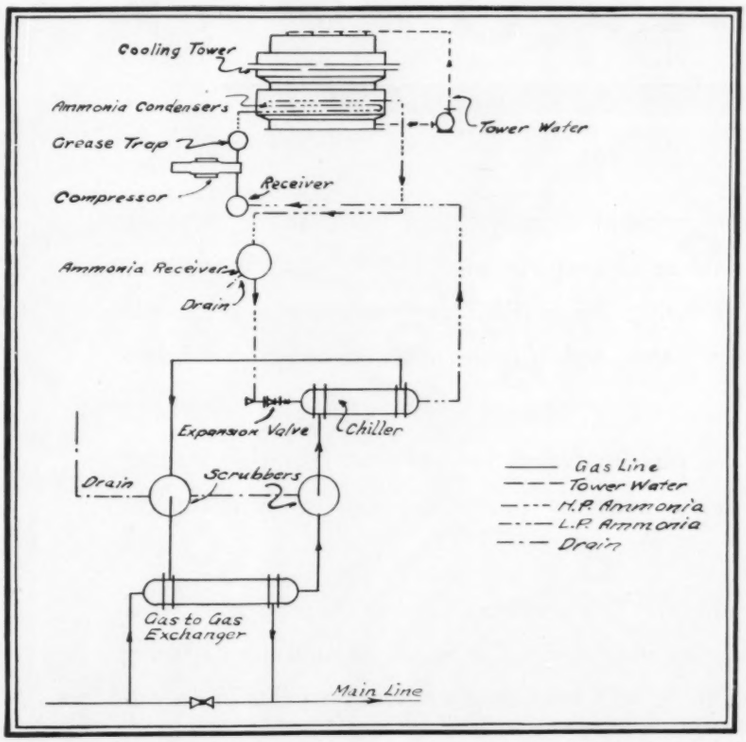
MERCO NORDSTROM VALVE CO.

Subsidiary of

PITTSBURGH EQUITABLE METER CO.

General Offices — Pittsburgh, Penna. Western Valve Factory—Oakland. Service offices in all principal cities.

Announcing~ the Completion of the First Refrigeration~Natural Gas Dehydration Plant in the West....



Flow diagram for Dehydration Plant showing simplicity of layout.

Now! Protect Your Pipe-Line Investment.

Internal corrosion of high pressure natural gas transmission lines is today a serious economic problem.

Elimination of destructive scale, with its attendant corrosion and consequent excessive drop in capacity of pipe lines, is now an engineering possibility. Corrosion elimination may now be economically accomplished through the installation of a REFRIGERATION—NATURAL GAS DEHYDRATION PLANT. The first of its kind is today successfully operating at the Ventura plant of the Industrial Fuel Supply Company.

A small initial cost insures positive protection of your large pipe-line investment.

Houston, Tex.
Washington, D. C.
Chicago, Ill.
St. Louis, Mo.

New York, N. Y.
Tulsa, Okla.
Oklahoma City, Okla.
Kansas City, Mo.

FLUOR CORPORATION
• LTD •
909 East 59th Street... ●... LOS ANGELES, CALIF.

September, 1933, Volume IX, Number 9, Western Gas is published by Western Business Papers, Inc., at 810 South Spring Street, Los Angeles, California. Subscription price (in advance) 25 cents the copy; $2.00 per year; 2 years, $3.00; $3.00 per year foreign. Entered as second class matter June 1, 1925, at the postoffice at Los Angeles, under the Act of March 3, 1879.

WHAT PRICE DELAY?

OUR Purchasing Department estimates that the cost of materials entering into the manufacture of cast iron pipe and fittings will advance from 25 to 30 per cent during the next 90 days; substantial price advances on some of these items, and in labor costs, already have taken place.

Accordingly, we are placing orders for our own materials insofar as possible, seeking every available protection against increases in manufacturing cost.

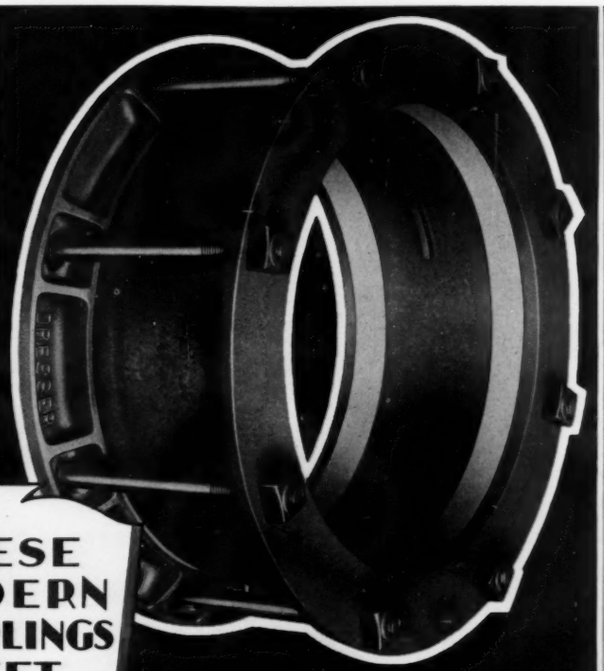
We realize, however, that this protection is merely temporary, and that eventually our manufacturing cost will increase beyond our capacity to absorb the differential. It will then become necessary for us to advance the price of our products.

The simple logic of this reasoning should urge on all prospective purchasers of cast iron pipe and fittings the obvious wisdom of PLACING ORDERS NOW!

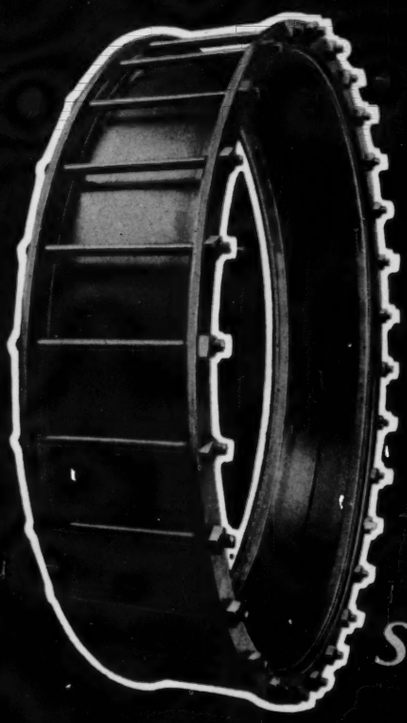
AMERICAN
CAST IRON PIPE
COMPANY
BIRMINGHAM, ALABAMA

CHICAGO KANSAS CITY CLEVELAND MINNEAPOLIS
DALLAS NEW YORK CITY LOS ANGELES SEATTLE
SAN FRANCISCO

BENEFIT BY USING THIS CONSTRUCTION FOR YOUR NEW GAS LINES



THESE MODERN COUPLINGS MEET EVERY NEED



Style 38

Here is the last word in joint construction for steel, cast-iron and all other plain-end pipe. The Dresser Steel Coupling, Style 38, is used on all sizes of gas lines from ⅜-inch to the largest mains laid. Write for complete information and prices, specifying the outside diameter and the kind of pipe on which couplings will be used.

Style 53

Here is the newest and most efficient cast joint: Dresser Cast Coupling, Style 53. Like the Style 38, it is equipped with rubber gaskets that have been specially developed and constantly improved for nearly half a century. These gaskets are *successfully* holding pressures on more than 100,000 miles of pipe. Style 53 can be furnished for A. G. A. cast-iron pipe up to and including 30-inch.

DRESSER COUPLINGS DOMINATE!

JOIN your new gas lines and mains the most modern way. Use Dresser Couplings. Then you will be *sure* of easy installation, extreme flexibility, complete uniformity of material and fit, permanent and *absolute* gas tightness, no service interruptions or maintenance costs.

S. R. DRESSER MFG. COMPANY
BRADFORD, PA.
In Canada: Dresser Mfg Co., Ltd., 32 Front St., W., Toronto, Ont.

DRESSER

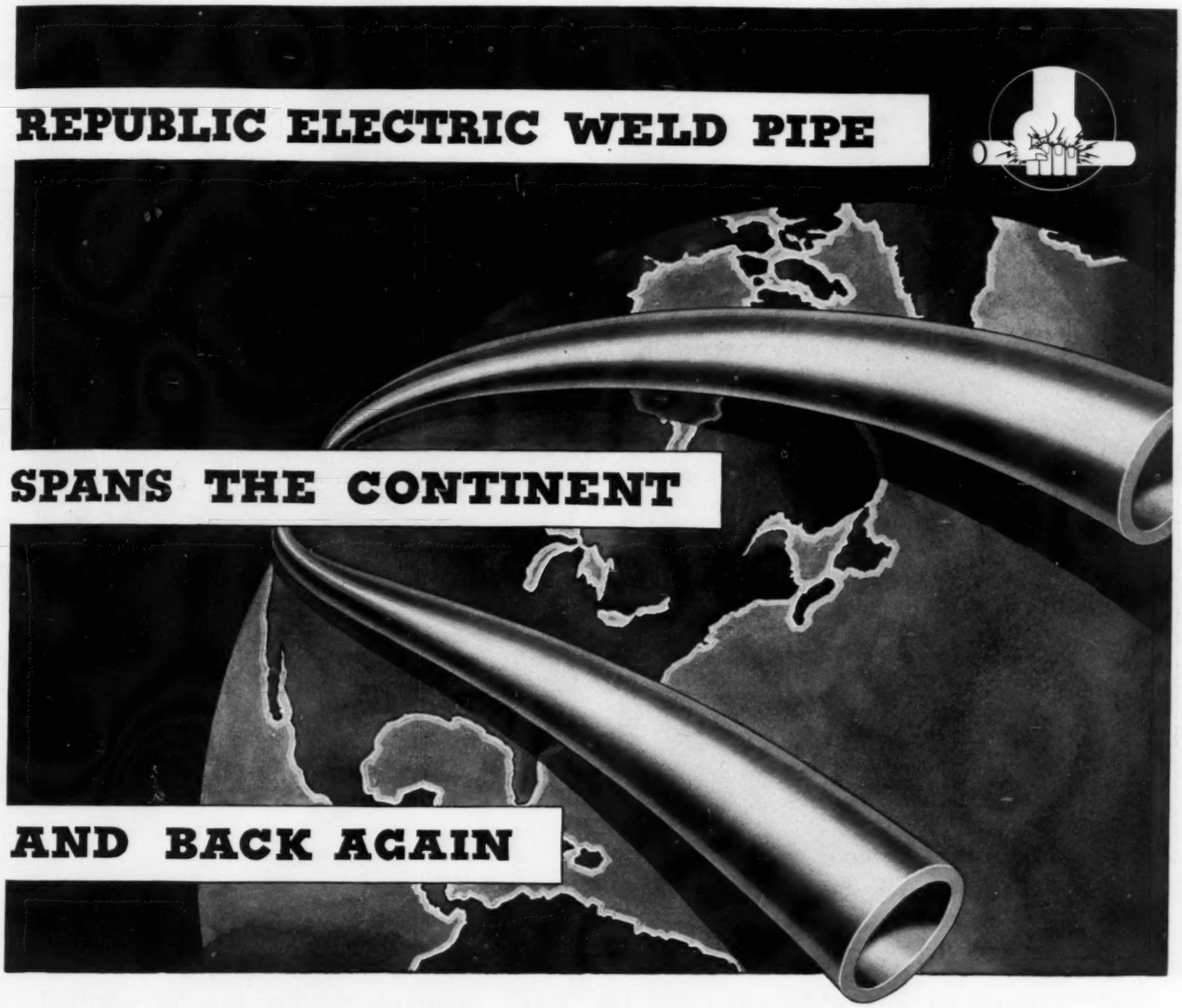
GAS-TIGHT

Cast iron pipe with gas-tight mechanical joints is establishing records of outstanding performance in high pressure service. There are several mechanical joints made by members of this Association. All are based on the stuffing-box principle employing rubber gaskets with follower rings. They differ in design but are fundamentally gas-tight.

The Cast Iron Pipe Research Association, Thos. F. Wolfe, Research Engineer, 309 Peoples Gas Building, Chicago, Ill.

CAST IRON PIPE

This mark on pipe is a pledge of economy
(Trademark Reg.)



WITH a number of companies buying Republic Electric Weld Pipe for installation all over the country, it's just a little difficult to visualize the tremendous mileage that has been placed in service during the last four years—but if it were all in a single line it would span the continent twice. This means that more than 7000 miles of this better pipe is now carrying oil, gasoline and gas to distribution centers.

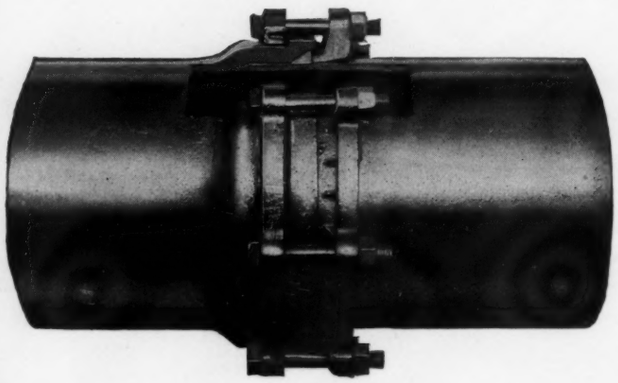
Republic Electric Weld Pipe was selected in every case because it is a different kind of pipe with many advantages. Flat steel strip is cold formed to a round and welded by electrical resistance. It is uniform in wall thickness, perfectly round, of uniform diameter, and as strong at the weld as at any other point in the wall. It is free from scale inside and out. These qualities mean tighter joints, pipe without thin spots in the wall, faster construction, easier, quicker welding at joints, and no loose scale to clog when liquids are turned into the line.

If you are interested in knowing more about this pipe that has won such wide recognition, write today for the story contained in our Booklet 210-B. The engineering information in it is well worth having on file.

REPUBLIC STEEL
CORPORATION
GENERAL OFFICES: YOUNGSTOWN, OHIO

REPUBLIC *Electric weld*
LINE PIPE • CASING • TUBING

Send for new Anthony Joint Handbook containing valuable data for gas superintendents and distribution engineers



The Gas-Tight Anthony Joint

If you have used Anthony Joint pipe you know that it saves time. There are only 3 parts to assemble—6 bolts to tighten—and the joint is complete.

If you have tested the Anthony Joint you know that it is gas-tight under pressures that exceed the average daily pressure on the line.

But whether or not you have had experience with the Anthony Joint you are undoubtedly familiar with the engineering principle on which it is based—the "stuffing-box" principle. Engineers recognize that wherever a moving part enters a pressure chamber the "stuffing-box" principle is universally applied to prevent leakage. It is adapted in the Anthony Joint through the use of a rubber gasket with follower and clamp rings.

Anthony Joint pipe is obtainable with either de Lavaud centrifugally cast pipe or with pit cast pipe and fittings. All rings, bolts and gaskets are interchangeable. Anthony Joint bends, tees and other fittings are also usable with plain end pipe. Write for complete data.

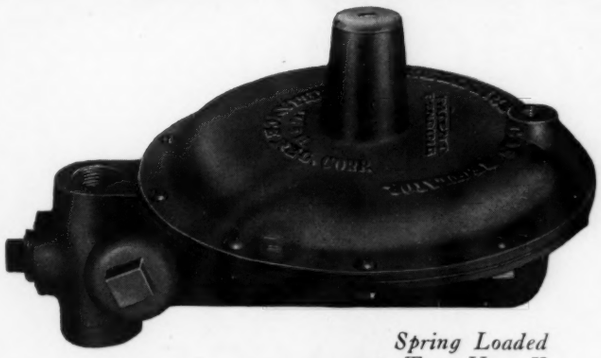
U. S. CAST IRON PIPE

UNITED STATES PIPE AND FOUNDRY CO., BURLINGTON, N. J. -:- SALES OFFICES: NEW YORK, BUFFALO, CLEVELAND, CHICAGO PHILADELPHIA, PITTSBURGH, DALLAS, BIRMINGHAM, KANSAS CITY, MINNEAPOLIS, SEATTLE, LOS ANGELES, SAN FRANCISCO

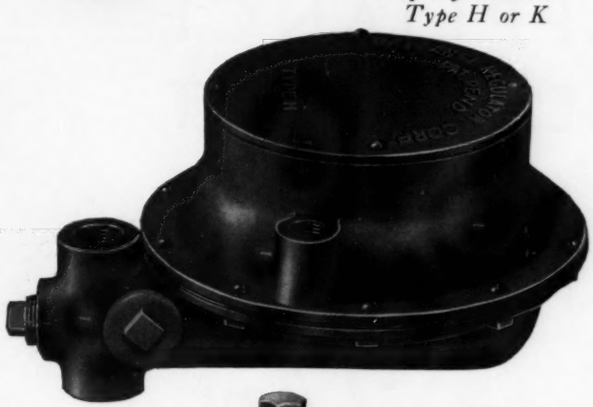
Copyright 1932, United States Pipe and Foundry Company

RELIANCE

REGULATORS

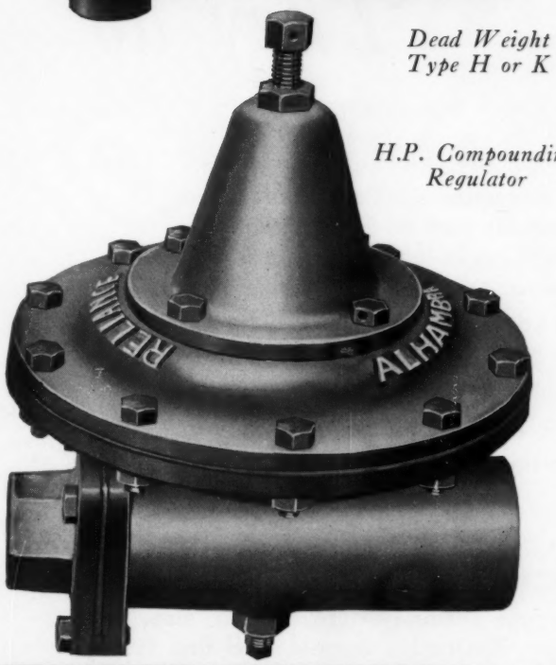


Spring Loaded Type H or K



Dead Weight Type H or K

H.P. Compounding Regulator



..MAINTAIN UNIFORM PRESSURE *for* Manufactured, Natural and Butane Air Gases

Reliance Regulators maintain uniform delivery pressures at extremely high rates of flow and have an exceedingly low lock up. Type H and Type K Regulators are made in spring loaded or dead weight types, with or without a mercury seal. Valve and valve seats are easily accessible for inspection and replacement through the hand hole, and adjustments for changing pressure are readily made.

The High Pressure Compounding Type Regulators in ¾", 1" and 2" sizes, are for reducing extremely high inlet pressures to intermediate pressures of between 5 and 40 lbs. They are extremely compact with high capacities and have a positive lock up.

The Reliance Organization also manufactures a high grade line of Industrial and District Regulators. These include Type A, weight loaded appliance regulators either with or without safety factor, and Type Y, spring loaded appliance regulators.

RELIANCE REGULATOR CORPORATION
1000 Meridian Ave. ALHAMBRA, CALIFORNIA

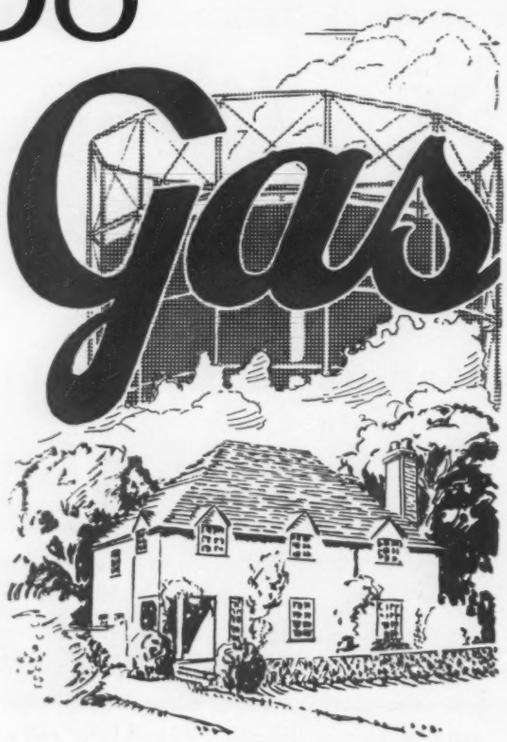
SALES—SERVICE

NORTHWEST GAS & ELECTRIC EQUIPMENT CO., Portland, Ore.
AMERICAN METER COMPANY—New York, Chicago, Pittsburgh, Philadelphia
MARYLAND METER WORKS—Baltimore
WESTCOTT & GREIS, INC., Dallas, Texas; Tulsa, Okla.

REGULATORS YOU CAN RELY ON — RELIANCE

D. McDONALD & COMPANY—Albany
METRIC METAL WORKS—Erie, Denver, Kansas City, Birmingham
NATHANIEL TUFTS METER WORKS—Boston
PACIFIC METER WORKS—Los Angeles, San Francisco

Do Gas APPLIANCE DEALERS GET MORE RESULTS BY TYING IN?



They do

TIE-IN advertisements are business-getters, yet they require neither large space nor expensive make-up. Everywhere in P. G. and E. territory, they are helping dealers do a better advertising job.

The Tie-in space used in our 291 daily and weekly newspapers during August, 1933, showed a 58% increase over the same month last year. And the total number of Tie-in advertisers nearly tripled.

Limited advertising budgets make shrewd advertisers. Tie-in advertising, a regular part of Gas appliance merchandising in the larger stores, is now being adopted by the most careful advertiser of all—the small dealer. His advertising dollars must bring quick results. He is using Tie-ins more each month. We believe this worthwhile evidence that they pay.

By simply stating the make, exclusive features, and price of your appliance in adjoining space, you make our desire creating advertisement action-getting. Here, also, your Tie-in capitalizes on from 20 to 60 inches of copy, illustrative appeal, and fine typography. And the result is that both advertisements get a maximum number of readers per thousand circulation. Surely, this business-getting combination of our advertising and yours should have an important place in your Fall selling program.

DO DEALERS HAVE TO PAY A PREMIUM FOR THIS EXTRA PULLING-POWER?

They do not.

REGARDLESS of rising price levels, TIE-IN advertisements will always be bargains. The yardstick of advertising value is "cost per sale." Whether an advertisement is cheap or costly depends on this alone.

If an advertisement has greater "pulling power"—if it attracts more readers and brings in more customers—it is not only better but cheaper. The "cost per sale" is proportionately reduced. The advantage of TYING IN is that the dealer advertisement has more pulling power, yet costs no more, and often less, than when published alone.

As TIE-INS enable a dealer to get the same results from a smaller advertisement, he can advertise more often on his regular budget. He gets more for his money from planned, systematic advertising than from spasmodic, shot-in-the-dark advertising.

Your business, too, will respond quickly to a TIE-IN program. It's REPETITION that counts.

YOUR TIE-IN AD HERE
TELLS PROSPECTS THAT
YOU SELL
THE APPLIANCES ADVERTISED BY
P·G·and E·

P · G · and E ·

PACIFIC GAS AND ELECTRIC COMPANY

OWNED - OPERATED & MANAGED BY CALIFORNIANS

Privately Owned Utilities' Tax Burden Constantly Increasing

An average of 80 cents for every monthly gas and electric bill rendered on Coast Counties Gas and Electric Company system is required for taxes. These taxes have mounted yearly regardless of decreased gross revenues. Out of every dollar of gross income received we pay over 13½ cents in County, State and Federal Taxes, in addition to which we are now called upon to pay a 2½ per cent Sales Tax on articles purchased for use in supplying service.

If privately owned public utilities were relieved from the present tax burden, such as tax exempt government owned utilities, present rates could be greatly reduced—every tax that has been shifted from the people to the utilities is actually paid by the consumers in their monthly service bills. Regardless of increased taxes, and decreased revenues, consumer's bills were reduced and service improved with the advent of natural gas in our territory.

The Company is now paying more for taxes each year than it pays in dividends to its stockholders.

Coast Counties Gas and Electric Company

Congratulations to the Pacific Coast Gas Association for its splendid record of accomplishment, notwithstanding adverse business conditions during these last three years. We join in the cordial welcome to delegates from the Pacific states.

SOUTHERN COUNTIES GAS COMPANY

The end of a "perfect" day
SUMMER showers at the instant turn of the faucet are hot weather joys that win the heart of every sportsman. Golfers know that a "140" temper is one of the hardest to control, but thanks to the automatic gas water heater, it only takes 140 seconds to be "singing in the shower" where worries vanish like magic.
Life isn't worth living without an automatic, and hot weather makes the self-action heater all the more desirable. In summer there are more baths to take, more clothes to wash and more "dried-on" dishes to cleanse.
Today is a good day to go shopping for an automatic. Prices are still below normal. Be sure to order a heater of sufficient capacity for the whole family. Remember there are 150 everyday uses for hot water. Whether it be heated in a teakettle, tank or boiler there is an item of fuel cost to consider.
Investigate the cost-per-gallon! You'll be surprised to learn that automatic hot water is most economical.
GAS APPLIANCE ASSOCIATION OF SAN DIEGO COUNTY
Representing those firms engaged in the promotion and sale of gas appliances
506 Electric Building

Reproduction of Recent Association Advertisement on Automatic Gas Water Heaters

Cooperative Selling

THE recently organized Gas Appliance Association of San Diego County is preparing for an extensive 12-month program of cooperative selling covering all types of space heating, automatic water heaters aud modern ranges. The program calls for concentrated sales activity and mass advertising. The sales promotion facilities of this Company are at the disposal of the Association and it is our sincere belief that such cooperative efforts will be highly successful.

SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO.

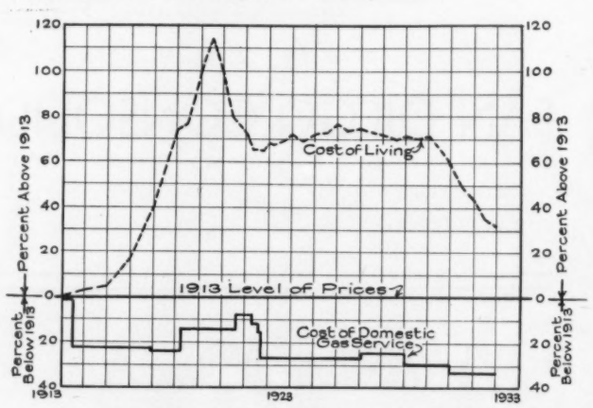
SOUTHERN CALIFORNIA GAS COMPANY
DEPENDABLE SERVICE
GAS

To the People in the Gas Industry—

THE cost of Gas Service to the Domestic Consumer is materially below pre-war levels. It has been consistently so, throughout. In contrast, the Cost of Living in the United States remains above the 1913 figures. The accompanying chart tells the story.

Energetic effort by all the commercial elements of the gas industry will build a structure of substantial prosperity upon this solid foundation of service at low cost.

Tell your customers about the economy of Natural Gas.



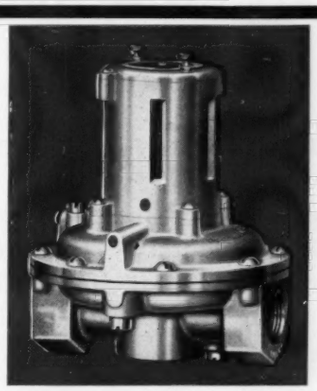
In the above chart, the Cost of Living is taken from reports of the United States Bureau of Labor Statistics. Cost of Gas Service is the Los Angeles experience, based on both price and heating value of the gas served.

NRA MEMBER U.S. WE DO OUR PART

LOS ANGELES GAS AND ELECTRIC CORPORATION

Control-o-Gas Products

Introducing the "THREE CONTROL-O-TEERS"



Control-o-Gas Thermo-Valve

For noiseless and positive temperature control these Control-o-Gas Thermo Valves are offered in four (4) sizes, from 1/2" to 1 1/4", inclusive.

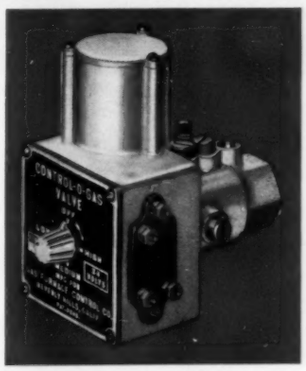
CAPACITIES
In B. T. U. Standard Gas

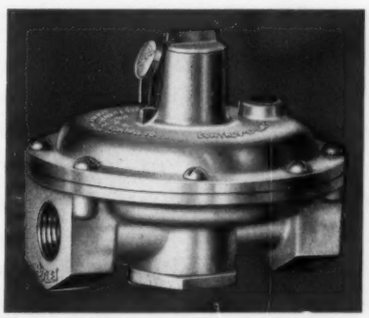
Size	Pressure Drop — Inches of Water				
	0.2	0.3	0.4	0.5	0.7
1/2"	59,000	72,600	84,500	95,000	113,600
3/4"	90,600	111,700	129,700	145,700	174,300
1 "	250,000	302,000	347,000	388,000	475,000
1 1/4"	337,000	410,000	467,000	578,000	620,000

Your attention is particularly directed to above capacities.

Control-o-Gas Three Degree Valve

This Control-o-Gas product has been used for years as a means of remote control for unit heating systems, conversion burners, etc., and where flexibility of heating is required. A switch of the push button type is used as the operating means and mounted on the plate are signal lamps indicating the position of the valve. Made in three sizes, 1/2", 3/4" and 1".





Low Pressure Regulator

Particular attention is called to this Control-o-Gas Low Pressure Regulator. Note large capacities in relation to sizes as per following table:

CAPACITIES OF REGULATORS
In B. T. U. Standard Gas

Sizes	Pressure Drop —Inches of Water				
	0.2	0.3	0.4	0.5	0.7
1/2"	60,600	74,800	85,000	96,000	113,600
3/4"	79,600	100,000	113,800	125,500	147,000
1 "	203,000	249,000	287,000	319,000	378,000
1 1/4"	258,000	311,000	356,000	398,000	476,000

These regulators are set and sealed at 4-inches water column pressure when leaving factory, unless otherwise specified.

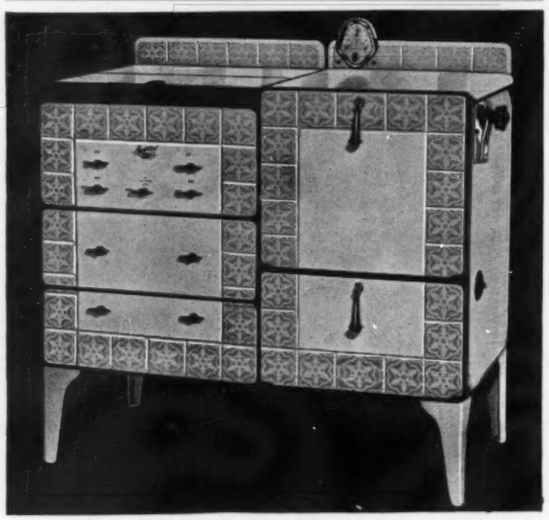
Manufactured and Distributed By

PAYNE FURNACE & SUPPLY CO.

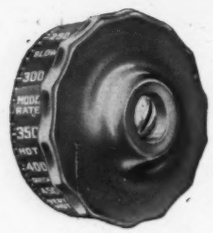
BEVERLY HILLS, CALIFORNIA

Magic Chef

AMERICAN STOVE COMPANY

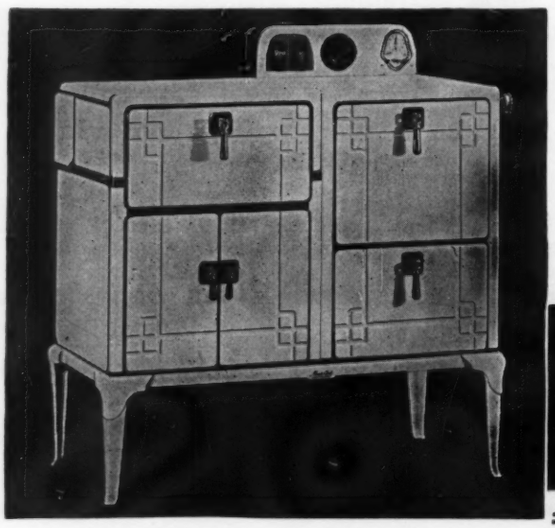


Patented



Look for the RED WHEEL
When you buy a MAGIC CHEF

Patented



A COMPLETE LINE

..that meets today's buying needs

WITH the buying swing gaining momentum daily, the Magic Chef line offers an unusual opportunity to gas range retailers. Magic Chef is a completely balanced line of related models that meets every buying requirement of size, style, taste and price.

To further strengthen the retailer's position, the Magic Chef line has advanced features of efficiency, convenience and economy found in no other gas range.

These features include the ingenious Magic Chef top burner which gives a thousand even heats . . . the Magic Chef Automatic Top Burner Lighter which lights any top burner automatically when the gas is turned on . . . the Sanitary High Burner Tray which conceals and protects pipes and valves . . . the famous Red Wheel Lorain Oven Regulator . . . the Grid-Pan Broiler, two-piece, with special basting reservoir... Automatic Time Control Clock.

Added to these advantages the Magic Chef retailer shares the benefits of extensive national advertising and the sales-winning prestige of Magic Chef at a "Century of Progress" Exposition. Representing the industry, American Stove Company was chosen to show an exhibit of the development of gas cooking appliances. Besides this exhibit, 5 out of 8 model homes at the Exposition are Magic Chef equipped.

AMERICAN STOVE COMPANY

World's Largest Manufacturer of Gas Ranges

BOSTON • • • • NEW YORK • • • • PHILADELPHIA
ATLANTA • • • • CLEVELAND • • • • CHICAGO
ST. LOUIS • • • LOS ANGELES • • • SAN FRANCISCO
SEATTLE

SOMETHING NEW

BY THE

WARD HEATER COMPANY

Two Floor Furnace Announcements

Thermal Control

● *Again Ward Heater Company takes leadership by introducing one of the greatest improvements in the history of modern home heating:* THE WARD BILT-IN THERMO-CONTROL.

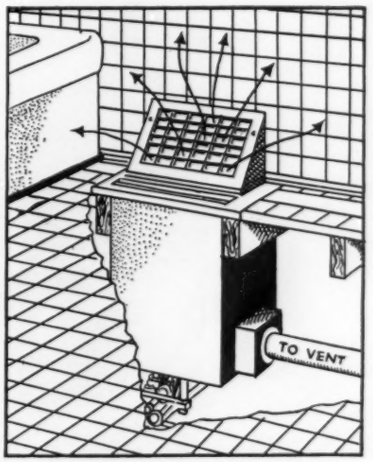
This device, especially designed, and now built into Ward Floor Furnaces as standard equipment, controls room temperature with almost human intelligence. Its action is positive, accurate, and efficient. Set your WARD BILT-IN THERMO-CONTROL for the temperature you desire, and the THERMO-CONTROL will maintain it, shutting off the gas before the rooms get too hot — and turning it on again before they get too cool. Ward Thermo-Control is *built in,* an *integral part* of the furnace.

Safety Pilot

Ward Floor Furnaces are also equipped with *Safety Pilots,* which give an additional element of safety not obtainable in floor furnaces until Ward made it standard equipment.

Gas Heat for Bathrooms

Ward has SOLVED *the bathroom heating problem for the gas industry.*



Ward Wall-he-tor

Ward has perfected a wall heater embodying the principles of safety and health that have made Ward Floor Furnaces famous the world over. This newest member of the Ward Family can be operated for *half a cent an hour.* And like all Ward products, it is a *vented* appliance.

The WALL-HE-TOR may also be used to provide economical heat for den, breakfast room, or small bedroom.

Write for Literature and Information About the Ward Franchise for Dealers.

WARD HEATER COMPANY

Established 1909

1800 W. Washington Blvd. Los Angeles, Calif. Telephone PArkway 9171

SPECIALISTS IN FLOOR FURNACE MANUFACTURING FOR 24 YEARS

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THE FIRST A. G. A. PRIZE CONTEST

on ELECTROLUX is

ALREADY A SUCCESS!

Sales returns for July show intensive, *productive* efforts on Electrolux in all parts of the country . . . For the hundreds of companies registered in this contest, there'll be no "dull months" *this* Fall!

GRATIFYING was the registration response of utility sales organizations to the first A.G.A. prize contest on Electrolux! Even more gratifying, if possible, is the way in which these companies have hung up Electrolux retail sales records during July!

And everything points to a profitable continuance of this Electrolux sales success during the months ahead! For the business is there. People are in a buying mood. They're refrigeration minded. And we have a product to offer that's far superior to competition.

It's not too late, even now, for companies who have not already signed up to get into the contest! Credit will be given for all Electrolux sales made since July 1st. The contest ends midnight, October 31st. And don't forget: all installations in your meter territory—whether made by yourself or by your sub-dealers—count in your total!

Prizes are $750 (first), $500 (second), and $250 (third) . . . worthwhile objectives! But there is even more than prize money to be gained by the company which gets behind this drive. Every Electrolux installed adds 1500 cubic feet to a customer's present requirements . . . gives a strong impetus to the sale of other gas-using appliances.

For further information, write at once to Mr. J. W. West, American Gas Association, 420 Lexington Avenue, N. Y. C.

Refrigeration Committee

AMERICAN GAS ASSOCIATION

420 Lexington Ave. . . . New York, N. Y.

THE WIDE USE OF NATURAL GAS AND CENTRALIZATION OF MANUFACTURED GAS PRODUCTION PRESENT PROBLEMS IN HIGH PRESSURE DISPLACEMENT MEASUREMENT WHICH THESE AIDS TO GOOD SERVICE ARE SOLVING . . .

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WESTERN GAS

"Reg. U. S. Pat. Off."

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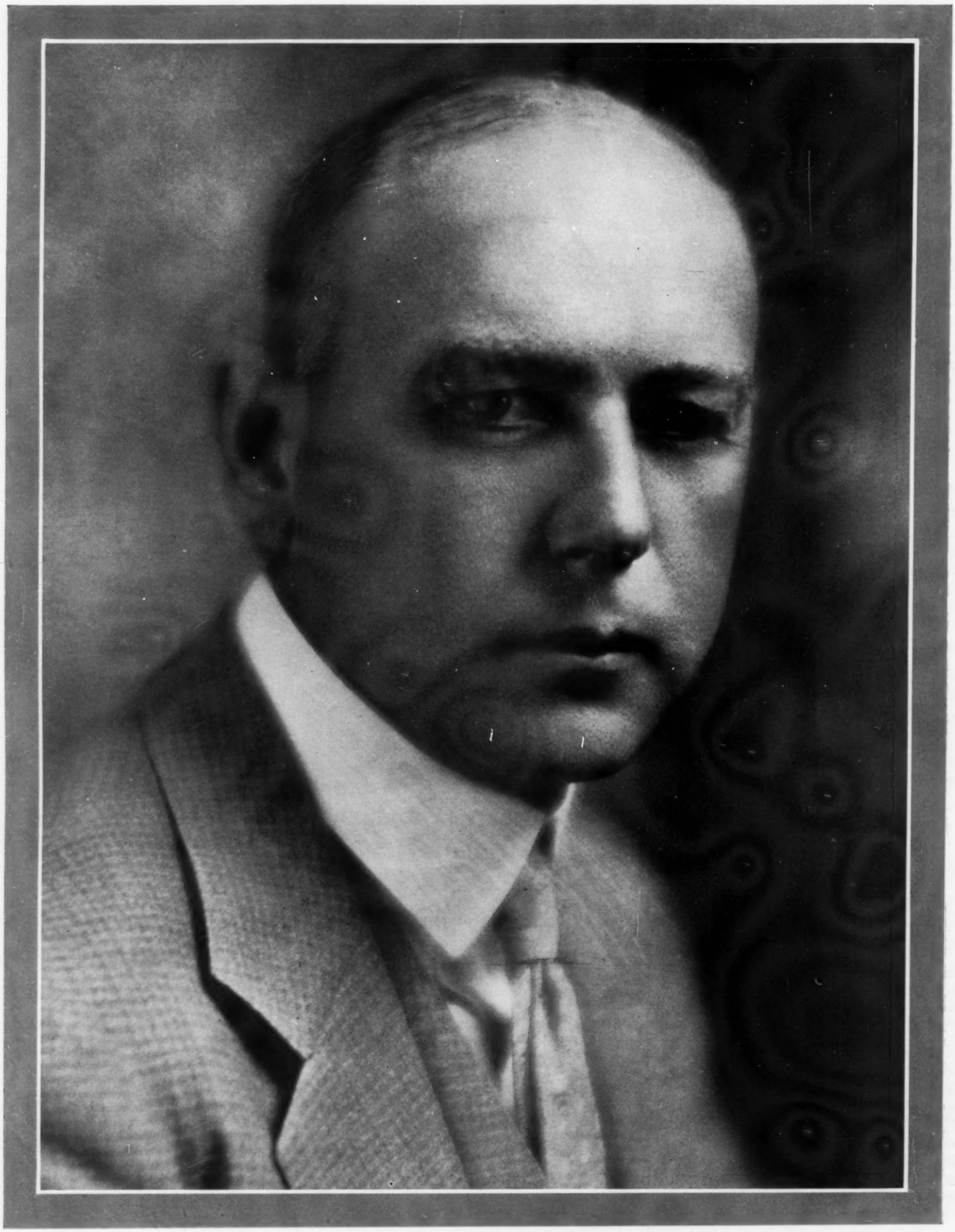

Harry L. Masser, vice-president and executive engineer of the Los Angeles Gas and Electric Corporation, as 1932-1933 President of the Pacific Coast Gas Association has guided the organization through an eventful year—the 40th in P.C.G.A history.

September, 1933

WESTERN GAS

"Reg. U. S. Pat. Off."

Vol. IX, No. 9

A Monthly Journal of the Gas and Gas Appliance Industries in *Western America*

A Foreword to the Pacific Coast Gas Association's 40th Annual Convention

ON September 13 Los Angeles will welcome you to the 40th Annual Convention of the Pacific Coast Gas Association, at the Ambassador Hotel. For 40 years the Pacific Coast Gas Association has carried on, uninterrupted, a program of research and development which has contributed much to our industry. The work of your Committees in these years has produced a compendium of standard practices for all of our departments. This task is not yet completed. So long as we are to progress, we will have work ahead of us.

Times change, and concurrently our problems change. Not many years ago, our executives had but very limited knowledge of present-day standards of corporation accounting; sales problems were much more elemental; gas-burning appliances had by no means reached their present degree of perfection, and our engineering technique and knowledge was far inferior to that of today.

Now, we are in a new era, with many entirely new problems to solve. We have passed through that adolescent stage of mechanical experimentation and development, and have entered a period where our executives are primarily concerned with problems of business administration under difficult political environment. All the major industries of the country face the same situation to a greater or lesser degree, but for the utility, the political phases are more far-reaching. The most successful utility in future years will be the one whose organization most clearly comprehends the public attitude, and is best able to "sell" itself to the people of its community. To begin with, the utility, like all other business enterprises, must have clean hands in every respect. With this foundation beneath us, our major job today is to procure a widespread public acceptance of the idea that the gas companies of the country are in truth of real worth and benefit to the communities they serve, and being such, they should have the public respect and support. The man who can contribute most to establishing in the public mind a recognition of the value of his company, will render the greatest service to the industry.

In keeping with existing economic conditions, the activities of the Association this past year have been limited and guided into those channels which offered greatest returns for our efforts and expenditures. Our Sections and Committees have done most creditable work, and I am sure their reports will be of substantial value and fully justify attendance at the Convention. Here you will have the opportunity which only a Convention provides, of being able to discuss problems with other men who have had independent experience in similar lines. Our recent Seattle meeting, because of its discussions, was one of the best we have had. The program for this Convention has been especially planned to provide adequate time for the discussion of technical details of various operating problems, and also to cover subjects of policy that will be of particular interest to executives. I am confident that this Convention will be very worth-while from the standpoint of work accomplished; the larger the attendance, the greater will be the value of this meeting to our industry.

HARRY L. MASSER,

President, Pacific Coast Gas Association

Utility Codes Approved

WITH codes of fair competition duly approved by the National Recovery Administration for the utility industry, the latter part of August found individual companies rapidly coming under the President's Reemployment Agreement. Readjustment of working hours and expansion of personnel are proceeding as rapidly as possible.

A code for the manufactured and mixed gas operating industry, and a closely similar code for natural gas companies, were prepared by A. G. A. committees, submitted to the NRA and approved on August 11. Containing provisions which may be substituted for Sections 2 to 7, inclusive, of the President's Reemployment Agreement, these codes place all companies in line to cooperate under the P. R. A. A code identical to those of the gas industry in respect to wages and working hours was submitted by the Edison Electric Institute and is now operative.

The American Gas Association and the Natural Gas Department expect to file industry codes with the NRA, which if given the President's approval will supersede the temporary agreements now being signed. These codes will be submitted to the industry.

The full text of the natural gas industry code appears below.

CODE OF FAIR COMPETITION FOR THE NATURAL GAS INDUSTRY

PURPOSES

The declared purposes of this code is to effectuate the policy of Title I of the National Industrial Recovery Act during the period of emergency.

DEFINITION

The Natural Gas Division of the American Gas Association affirms that it imposes no inequitable restrictions on its membership and participation in its activities, and it is truly representative as a national association of the natural gas industry.

The term "employer" as used herein includes every person, firm or corporation engaged in the production, transmission and/or distribution of natural gas for domestic, commercial and/or industrial consumption.

The term "employee," as used herein, shall include all persons employed in the conduct of such operations.

I. LABOR PROVISIONS

As required by Section 7 (a) of Title I of the National Industrial Recovery Act, the following provisions are conditions of this code:

1. Employees shall have the right to organize and bargain collectively through representatives of their own choosing, and shall be free from the interference, restraint, or coercion of employers of labor, or their agents, in the designation of such representatives or in self-organization or in other concerted activities for the purpose of collective bargaining or other mutual aid or protection.

2. No employee and no one seeking employment shall be required as a condition of employment to join any company union or to refrain from joining, organizing or assisting a labor organization of his own choosing; and

3. Employers shall comply with the maximum hours of labor, minimum rates of pay, and other conditions of employment, approved or prescribed by the President.

II. CHILD LABOR

After August 31, 1933, no person under sixteen years of age shall be employed, except that persons between fourteen and sixteen years of age may be employed for not to exceed three hours a day and those hours between 7:00 a. m. and 7:00 p. m., in such work as will not interfere with hours of day school.

III. HOURS OF EMPLOYMENT AND WAGES

The following paragraphs in this section III are in substitution for paragraphs 2 to 7, inclusive, of the President's Reemployment Agreement:

(A) No employee shall work for more than an average of 40 hours per week during any six weeks' period, except those specified in Paragraph (B).

(B) Load dispatchers, well operators, station operators, and emergency maintenance and repair employees, their attendants, crews and helpers, if highly trained and not readily replaceable, whose duties must be continuously performed in order to render the public a safe and continuous service, may be employed not in excess of 48 hours per week, so long as other competent employees are not readily available for such work, and in emergencies such employees may work more than 48 hours per week, but in no case shall the hours worked exceed an average of 48 hours for six consecutive weeks. All employers subject to this code shall proceed with the training of additional employees as rapidly as is consistent with the rendition of safe and continuous service, so that by March 1, 1934, as many employees as possible may be re-classified under the 40 hours per week limitation; and report shall be made on said date of the extent of such re-classification to the National Recovery Administration.

(C) The maximum hours fixed in the foregoing paragraphs shall not apply where not more than two persons are employed in communities of less than 2,500 population, which communities are not part of a larger trade area; nor to employees engaged on emergency work; nor to outside salesmen; nor to employees in a managerial, executive, administrative or supervisory capacity, who now receive more than $35.00 a week. Population for the purposes of this agreement shall be determined by reference to the 1930 Federal Census.

(D) Employees shall be paid at the rate of:

(1) Not less than $15 a week in any city of over 500,000 population or in the immediate trade area of such city;

(2) Not less than $14.50 a week in any city between 250,000 and 500,000 population or in the immediate trade area of such city;

(3) Not less than $14 a week in any city between 2,500 and 250,000 population or in the immediate trade are of such city, and

(4) In towns of less than 2,500 population all wages shall be increased by not less than 20 per cent, provided that this shall not require wages in excess of $12 a week.

(5) This paragraph shall apply to all employees except those covered by the provisions of the following paragraph (E).

(E) Employees of the classes who on July 1, 1933, were paid on an hourly rate shall be paid not less than 40c per hour, unless the hourly rate for the same class of work on July 15, 1929, was less than 40c per hour, in which case the rate of pay shall not be less than the July 15, 1929 hourly rate of pay and, in any event, shall not be less than 30c per hour; *Provided* that learners may be paid not less than 80 per cent of the minimum wage rate provided in the above schedule, but the total number of learners shall not exceed 5 per cent of the total number of employees employed by any employer subject to this Code.

IV. ADMINISTRATION

The Natural Gas Division of the American Gas Association is hereby designated the agency for administering, supervising and promoting the performance of the provisions of this Code by the members of the natural gas industry. The Natural Gas Division of the American Gas Association shall appoint a Recovery Executive Committee to exercise such functions on behalf of the Natural Gas Division of the American Gas Association and the facilities and departments of the Natural Gas Division of the American Gas Association shall be available to make the administration effective and efficient.

(Continued on Page 73)

An International Outlook *for* 15th A. G. A. Convention

CHICAGO entertains the International Gas Conference and 15th Annual Convention of the American Gas Association this month, being host to the gas industry for the first time since 1927. Something more than a convention is in order, for with the Century of Progress International Exposition at its front door, the national conference has been broadened to include the industries of other lands. Both the general and sectional programs which transpire from September 25 through the 28th are spotted liberally with addresses from overseas gas leaders. International aspects of the convention are particularly evident in the opening session program, at which messages will be brought by the presidents or past-presidents of official gas organizations in England, France, Switzerland, Belgium.

Principal events tentatively scheduled for general sessions are set forth below, some changes in program being possible prior to convention dates. All general sessions and most of the sectional meetings are at Hotel Stevens.

General Sessions: President Arthur Hewitt, presiding.

Tuesday, September 26, 10:00 a. m.

Call to Order: President Arthur Hewitt, Toronto, Ontario
Welcome to Foreign Delegates: Hon. Rufus C. Dawes, President, A Century of Progress; Hon. E. J. Kelly, Mayor of Chicago
Presentation of Foreign Delegates: President Hewitt
Address: The Gas Industry from the British Standpoint—F. P. Tarratt, President, Institution of Gas Engineers, Newcastle-upon-Tyne, England
Address: Present Condition of the French Gas Industry—A. Baril, Past-President, French Gas Association, Paris, France
Address: The Purpose of International Collaboration in the Gas Industry—Dr. Fritz Escher, President, International Gas Union, Zurich, Switzerland
Greetings from the Belgian Gas Fraternity—H. de le Paulle, President, Belgian Gas Association, Brussels, Belgium
Address: The American Gas Industry—President, Arthur Hewitt, Toronto, Ontario

Wednesday, September 27, 10:00 a. m.

Treasurer's Report
Report: The Association's Job—Alexander Forward, Managing Director
Election of Officers
Address: Executive Responsibility for Sales Promotion—E. M. Tharp, Vice-President, Ohio Fuel Gas Co., Columbus, Ohio
Address: Industry Planning for Greater Sales—Conrad N. Lauer, Chairman, National Directing Committee of Executives, Philadelphia, Pa.
Discussion: The Industry and the National Industrial Recovery Program

Thursday, September 28, 10:00 a. m.

Report of Time and Place Committee—W. Cullen Morris, Chairman, Consolidated Gas Co. of New York, New York, N. Y.
Address: The Industry's Achievement in Research—F. C. Weber, Vice-President, Brooklyn Union Gas Co., Brooklyn, N. Y.
Report of Resolutions Committee
Award of Medals
(a) Beal Medal
(b) Chas. A. Munroe Award
Address: What's Our Job?—Dr. H. N. Davis, President, Stevens Institute of Technology, Hoboken, N. J.
Address: About Utility Regulation—Lester Hooker, President, National Association of Railroad and Utilities Commissioners, Richmond, Va.

Accounting Section: J. M. Roberts, of The Peoples Gas Light & Coke Co., chairman.

To comment briefly upon the excellent array of discussions to come before the various divisions, the Accounting Section has its regular committees bringing in reports on customers' relations, general accounting, customers' accounting, accounting machines, office management, classification of accounts. Thomas Carmichael, engineer and general manager of the Portsmouth Gas Co., Portsmouth, England, will contribute an address on "Meter Reading and Collecting of Accounts."

Commercial Section: Walter C. Beckjord, Boston Consolidated Gas Co., chairman.

Following Mr. Beckjord's introductory address the section will hear T. P. Ridley, superintendent and commercial manager, Newcastle-upon-Tyne & Gateshead Gas Co., Newcastle-upon-Tyne, England, in a review of his industry's commercial development. Kitchen modernization is a key theme at this year's meeting, with a playlet and a symposium of short talks due on the subject. Market surveys, refrigeration, home heating, will get proper attention.

Manufacturers' Section: D. B. Stokes, United States Pipe and Foundry Co., chairman.

The manufacturers will meet at the Blackstone Hotel, and important aspects of the national recovery program will be brought before them in addresses and discussions. George W. Bean, the A.G.A. representative in Washington, D. C., will confer with manufacturers and gas company representatives during the convention on questions relating to use of gas fuel on government projects.

Natural Gas Department: H. C. Cooper, Hope Natural Gas Co., chairman.

This program was published in full on Page 32 of *Western Gas* for July, and constitutes one of the srtongest ever put together for natural gas men. Outstanding executives will be heard on currently vital subjects, among them those of taxation as relating to utilities, legal problems in gas production and transportation arising out of the economic depression, rate schedules for load building, emergency substitutes for natural gas, relation of gas reserves and market requirements. The executive, management and advisory committees of the Department will hold their annual dinner the evening of Monday, September 25, the business program taking place during the day.

Home Service: Ruth Kleinmaier, Central Hudson Gas & Electric Corp., chairman Home Service Committee.

A Home Service Breakfast is arranged for Wednesday, Septmeber 27, with a schedule of 2-minute talks by home service directors, and brief addresses on such topics as individual cookery classes, trade dealer contacts, advertising home service, cookery classes for salesmen, traveling kitchens, theater cooking schools, kitchen modernization.

Industrial Gas Section: E. L. Wilder, Utility Management Corp., chairman.

"Watson House—An English Research Centre," an address by C. A. Masterson of the Gas Light & Coke Co., London, contributes the international touch to the industrial men's program. Discussions on present aspects of competitive fuel markets; advertising industrial applications for domestic load promotion; competition, sales methods and servicing in the hotel, restaurant and bakery field, will round out the program. The Midwest Industrial Gas Sales Council will convene in its regular fall meeting on the afternoon of Thursday, September 28.

(Continued on Page 73)

Previewing the 40th Convention

By D. L. SCOTT

General Chairman
1933 Annual Convention
Pacific Coast Gas Association

THIS year's Annual Convention will be compounded of the serious and the social according to the formula of the greatest effectiveness in the study of the gas industry's present problems. That means just enough of the social to add zest to the serious and maintain the spirit of good fellowship essential to the easiest cooperation and the cultivation of friendship. Accordingly, this year you will not come expecting much display of tinsel or sounding of trumpets. But you will expect to experience that meeting of the "best minds" which, after all, leaves the best after-taste and the longest glow of satisfaction.

Session by session, the program invites the attendance of the people of the industry at a series of discussions labeled as to the theme of each. The ensuing sketch is in explanation.

WEDNESDAY, SEPTEMBER 13

Forenoon: General Session. This will provide for the usual routine business of the Association and a business address of high character.

Noon: Fellowship Luncheon. This will be an informal luncheon, without program. It will be the much-valued opportunity to talk things over with those other people in the industry whom you contact too infrequently in the ordinary course of business.

Afternoon: Parallel Sessions. All the Sections will hold sessions this afternoon. The Technical Section, Guy Corfield, chairman, will program its Transmission and Production Committees. The Accounting Section, R. N. Dreiman, chairman, will discuss the subjects of Fixed Capital Records, Stores Accounting Procedure, Preparation of Financial Reports, Accounting Control for Collections and Meter Deposits, and Statistics. The Manufacturers Section, R. L. Hinckley, chairman, will hold a business meeting. The Commercial Section, F. U. Naylor, chairman; the Advertising Section, Douglas Buckler, chairman; and the Public Relations Section, D. L. Scott, chairman, all are working out programs for this period.

Swimming Party; Diving Exhibition: A swimming party for ladies of the Convention will take place Wednesday afternoon, and will be followed by a diving and swimming exhibition with some of the best aquatic talent of the Southland participating.

Evening: Dinner and President's Reception. The dinner in this case will be another programless affair, with fellowship and informal conference as the objectives. The President's Reception, following the dinner, will be an entirely separate function. Dancing will complete the day's routine.

THURSDAY, SEPTEMBER 14

Early Morning: Home Service Breakfast. This get-together will be under the leadership of Mrs. Katherine Rathbone.

Forenoon: General Session on Load Building. This theme is recognized as of paramount importance under the present conditions. The people in all phases of the industry have a heavy stake in this aspect of the business, and doubtless will manifest it by their attendance and interest.

Noon: Men's Speaking Contest Luncheon. The contest will be conducted by W. A. Worthington, Speaking Contest Director. The theme is "The Utility's Relation to Social Progress," and the contestants will discuss, extemporaneously, some phase of the subject selected on the evening preceding.

Afternoon: Parallel Sessions. The Technical Section will continue its discussions, devoting the period to the work of its Distribution Committee. A Customer Relations Conference, under the chairmanship of Oscar L. Moore, will be staged by the Public Relations Section. Other sections which have no separate meetings at this time are earnestly invited to participate in this conference. It is anticipated that the Women's Public Speaking Contest, under the direction of Mrs. Jeanette I. Rees, may be a part of this program. Customer relations people from the electrical industry also are expected to participate in the conference.

Ladies' Golf Tournament: This traditional event will be played on the Ambassador's pitch-and-putt course, at 2:30 Thursday afternoon. There will be no entrance fee.

Evening: Dinner and Parallel Sessions. Section dinners at the Ambassador are in preparation. These dinners, for the more part, will be programless get-together affairs. The Technical Section will employ the time in the completion of its consideration of the Distribution Committee work. The Women's Committee also will hold its annual dinner business session.

FRIDAY, SEPTEMBER 15

Forenoon: General Session on the Present Business Situation. This session will be devoted to the consideration of the major business problems of the day. The best opinion of the leaders of the gas industry and the National Recovery Administration will be sought through the forum of this meeting.

Noon: Fellowship Luncheon. No program. Also, a luncheon will be given for visiting ladies, by Mrs. H. L. Masser.

Afternoon: The Offerings of the Sections. Each Section has been invited to put its best foot forward in this session. Advance notices indicate some very profitable offerings. Final convention business, except announcement of awards, will be transacted.

Evening: Annual Banquet and Ball. The serious purpose of the convention will extend into this feature of the annual meet also. LeRoy M. Edwards,

(Continued on Page 73)

PACIFIC COAST GAS ASSOCIATION

TECHNICAL SECTION

Guy Corfield, Los Angeles Gas and Electric Corporation, General Chairman

Foreword: THE Association year now coming to a close has been an active one for the Technical Section's committee organizations. As is apparent from the reports published in the following pages, the work of the Section has produced a considerable body of useful information, and operating practice in the industry should benefit accordingly.

GUY CORFIELD
General Chairman Technical Section

F. A. HOUGH
Distribution Committee Chairman

B. M. LAULHERE
Transmission Committee Chairman

C. P. JOHNSON
Production Committee Chairman

Owing to a restricted budget this year the Association is under the necessity of curtailing its publication expenditures and therefore is unable to adhere to the usual procedure of printing committee reports in their entirety in this pre-convention issue of *Western Gas*. The technical data that follow do not, therefore, include all the material in the several reports nor all the reports that were submitted. Selections have been made by the Technical Section Publications Committee with the view of printing as far as possible material that is most representative, of greatest general interest, or of most immediate significance; other contributions of equal technical value have of necessity been postponed for the complete printing of all data in the Annual Proceedings. There are available, however, a limited number of mimeographed copies of all papers, which will be distributed among our technical membership and serve as a basis for discussion of all reports at our Convention Sessions.

GUY CORFIELD,
General Chairman, Technical Section

DISTRIBUTION COMMITTEE

F. A. Hough, Southern Counties Gas Company, Chairman

Safe Gas Distribution Practice*

METHODS FOR ESTABLISHING RESPONSIBILITY FOR DAMAGE OCCURRING FROM EXPLOSIONS†

GAS men and state officials, in their efforts to make gas distribution service safer are confronted with various complicated problems from time to time. In recent years these problems have tended to increase with the use of mechanical appliances and with the ever increasing diversity of industrial utilization of gas. The solutions of the problems which arise are not always obvious, as is shown by the fact that even the most capable engineers differ in their opinions of the best way to overcome a particular hazard of gas distribution practice, or of the best method to establish the responsibility for the damage resulting from explosions.

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Survey of Related Literature

Investigations and studies of gas explosions bring out many lessons that should be valuable to operators and employees of gas companies at times of emergencies, either in preventing catastrophes, or in establishing the cause of explosion. Many of the lessons are not new, but important enough to merit further study by those working with gas. The following lessons are abstracted:

Need for Authentic Information Concerning the Explosion That Has Taken Place:

1. *The Establishment of the Origin of Explosion:* An explosion is defined as "a violent bursting or expansion with noise following the sudden production of great pressure as in the case of explosives or a sudden release of pressure as in the disruption of a steam boiler". Although the definition just cited has not drawn any distinction between the two quite different origins of explosion, nevertheless it is of the utmost importance for the investigator to be able to establish the difference between the two distinct phenomena. In case of explosion due to disruption of an equipment caused by either faulty construction or use above its rated capacity, the responsibility for the damages resulting from explosion could be established without any argument between the consumer and the distributor of the commodity used for fuel.

2. *Determination of the Nature of Explosives:* Gas engineers will, therefore, be directly concerned with the explosions that involve the presence of explosives. Even though natural gas is not of itself explosive, its chemical makeup contains everything to be suited to cause explosion when mixed with definite amounts of air.

It is true that outside of the definite limits of gas and air ratio, natural gas would not even by itself sustain combustion, still the potentiality to become explosive will always offer a possibility for doubt in the controversy of establishing the responsibiiity for the damages. The problem of determination of the nature of explosive is very difficult because the distinction between the character of the destruction done by either type of explosive is very uncertain. The only general statement which could be made in regard to them is that the "dynamiting" or the use of explosives that contain all the elements necessary upon ignition to complete an almost instantaneous chemical reaction with the resultant development of great pressure has a localized nature, is confined to a small part or section of the equipment or the building, while the force of expansion of gaseous explosions distributes itself equally in all directions. The dynamiting in some cases could be established by the container or the wrapping material used in setting off explosives. The presence of obnoxious gases in the air after explosion would be considered as a material evidence, provided of course their nature could be definitely established by chemical analysis. From this angle, it would be a commended practice for the investigator to obtain samples of the gaseous atmosphere immediately upon arrival at the scene of explosion or to notify the utility's chemist to do so in case of the absence of the necessary equipment. Chemical analysis of the sampled atmosphere will constitute the most valuable material evidence during the process of determination of the nature of explosive.

3. *Source of Explosive:* Upon establishing the nature of ex-explosive, the chief endeavor of the investigator should be confined to the findings of its source of supply. Leak-indicating devices now on the market will render indispensable service in tracing back the possible sources of inflammable gases or vapors. In more detail, this question will be discussed later under the heading of preventive measures; here, it will suffice to state that there are known at the present many substances which, in vaporized state, form air mixtures easily mistaken for the natural gas-air mixtures from the standpoint of destructive hazard. Having established that the explosion was of a gaseous nature, further study may prove that it involved inflammables other than natural gas, thereby shifting the responsibility for the damages from the losing party to the winner in the controversial dispute.

4. *Reinstatement of Actual Conditions Just Preceding the Accident:* The solution of the problems of responsibility for the damages resulting from explosion is greatly simplified by the possibility of reestablishing the most unbiased picture of the general operating conditions prior to explosion. Although technically this part of investigation is conducted by the legal departments, nevertheless the supplementary information obtained by the engineering staff would in no way interfere with the course of investigation. The immediate contact of the witnesses to the explosion would be the most logical thing to begin with. The question of the part played by the human equation in the events resulting in explosion could not be determined, so far, by any other means than by the method of testimonial evidence. A very involved legal procedure, based on the material evidence accumulated during the process of investigation, quite often terminates by the verdict "accident" as a result of the testimony given by the witnesses. The technical man, in accumulating the testimonial evidence, is more apt to recognize the little details, the apparently insignificant neglect in compliance with the rules set for the safe operation or practice, and thereby render a very valuable share of his information toward establishing the responsibility for the damages.

NEED FOR PREVENTIVE MEASURES

1. *Dissemination of Information Concerning Explosive Air Mixtures.*

(a) of Gas: The public must be informed of the danger that may occur if gas is not properly utilized and must be instructed as to proper precautions in handling gas. Dissemination of this information should not create a general prejudice against gas any more than against other commodities that may cause injuries through improper use. Giving information on the safe utilization of "gas" should not cause the public to stop using it any more than safety-first education should stop people from crossing streets. In both cases there are dangers, but when safety measures are applied, the number of accidents are reduced and the problems of establishing the responsibility for damage, in case of accident, considerably simplified.

(b) of Refrigerants: The Bureau of Mines was interested in the question of "The Flammability of Refrigerants", because as American mines are developed to greater depths, attended by higher working temperatures, methods of cooling the air supplied to these deep workings have became necessary. Refrigerants, if used underground, should from the standpoint of safety be non-flammable. The investigation proved conclusively the explosive properties of several commonly used refrigerants, such as methyl and ethyl chlorides, ammonia, etc., and even established that the upper and lower limits of flammabilities of their mixtures with air may be calculated fairly accurately by LeChatelier's law. The results obtained are very important. Industrial concerns engaged either in the manufacture or utilization of refrigerants may in some stage of their operations have conditions of potential hazard from explosibility standpoint and there is no reason why the management should not be held responsible for damages in case of accident.

(c) of Paint and Lacquer—Solvent Vapors: The phenomenal increase in the use of nitrocellulose products has been accompanied by many inquiries relative to the hazards attendant on their production. The chief hazard is believed to lie in the accumulation of mixtures of nitrocellulose, pigment, gum dust and lacquer solvent vapors. Dust accumulations of this kind are known to ignite almost as readily as a gas, owing to the fine state of subdivision. At present, all the information concerning the concentration ranges of explosive mixtures with air of generally used lacquer solvents, hydrocarbon diluents and alcohols are available and the lack of information concerning their accessibility to the plant operators, quite definitely establishes the responsibility for the consequences of the explosion, provided, of course, that all the measures for safe operation of "gas" were rigidly conformed to.

(d) of Dust: Twelve experimental dust explosions at the Arlington, Virginia, experiment farm of the United States Department of Agriculture, October 4, 1932, demonstrated the deadly and destructive power of certain dusts when they explode. The experiment also demonstrated construction methods which minimize the destructive force and have helped reduce the annual dust explosion loss from $4,160,000 in 1921 to $1,100,700 in 1931.

Grain elevator dust, soap powder, starch dust, milk powder, sugar dust, wood charcoal dust, wood dust and cork dust were definitely classed among contributing elements for unsafe operations and necessitated the development of safety codes for dust explosion prevention in grain handling and manufacturing establishments.

(e) of Seepage: Seepage of natural gas or methane, the main constituent of natural gas, occurs in certain formations and there are several cases on record where explosive mixtures of this gas with air have been formed in underground workings in California and resulted in explosions. Seepage along the rights-of-way of distribution systems, due to leaks in the system, are also known and the danger of gaseous accumulations in manholes, tunnels and other sub-surface structures has been recognized and due consideration has been given to the presence of these gaseous accumulations, at least to the extent of keeping the potential hazards under a close observation. The phenomenon of seepage is common to all gaseous substances; to differentiate the natural occurrence from the seepage due to leaky mains, periodic gas analysis of atmosphere is necessary. The results of analysis will in many cases establish indisputably the responsibility for the hazard.

2. *Surveys.*

The ever-present and urgent necessity for surveys is justified by good and valid needs for having some knowledge of the conditions existing in the area occupied by the gas distribution system. The most direct application of the information gained by a survey comes at the time of a gas fire or gas explosion, when it is vitally important to have a maximum knowledge of conditions prior to the explosion in question, in order to establish the responsibility for the resultant damages. However, unless a regular procedure of ascertaining, recording and filing the data is followed, the necessary information may not be available for efficient use when and where it is required.

(a) By Whom Surveys Should Be Made.

There seems to prevail a fixed impression that a survey can only be made by experts. If a high degree of absolute accuracy were demanded, this would be true, but the essential requirements of such surveys do not demand anything more than the determination of the approximate magnitude of existing air conditions, primarily from the standpoint of explosive hazard. The survey need not be elaborate or require much time. Individual requirements, of course, govern the frequency of the observations. The survey in "risky" industries should be made often enough to keep the gas utility officials up-to-date in the essential features of operating conditions.

(b) Instruments That May Be Used.

1. *Hot Wire or Filament Type:* The principle of indicating the presence of combustible gases in air, either by differential temperature effect induced by the gases when in contact with a catalyst to promote combustion around a resistance wire or by the increased resistance of the heated filament surrounded by the atmosphere of combustible gases-air mixtures as compared to the resistance of the heated filament in contact with pure air, dates back many years, but its practical application in the form of an instrument has been developed only recently. These instruments depend on the fact that the heat developed by combustion of all the commonly en-

countered inflammable gases, when mixed with air to a concentration equal or proportional to the lower explosive limit, is approximately the same. The instruments are scaled to read from 0 to 100 per cent explosiveness for any inflammable gas. They will therefore indicate the degree of hazard that exists in any enclosed space with respect to the nearness of explosive concentrations, regardless of the kind of inflammable gas present. If the gas is known the actual concentration can be very closely approximated. For instance, the lower explosive limit of natural gas is approximately 5 per cent of gas in air. If the indicator dial reads 50 per cent, it means that natural gas is present in the amount of approximately 2.5 per cent. Inasmuch as the scale can easily be read to an accuracy of 5 per cent of explosiveness, it follows that a concentration of natural gas equal to 0.25 per cent in air can easily be detected. By means of air-diluting devices attached or attachable to these instruments, high concentrations of gas can be diluted by known volumes of air to bring the mixture within the scale range of the instruments. Four self-contained and portable instruments are now on the market and in general use in the Southern California territory. They are as follows:

U.C.C. (Union Carbide and Carbon Company)
(a) Combustible Gas Indicator "50C"
(b) All Service Gas Indicator. This indicator, in addition to indicating the per cent explosiveness of the atmosphere under test, carries a Baby Wolf Safety Lamp, whereby atmospheres deficient in oxygen can be discovered because of extinguishing of the flame, and also a chamber in which the unknown atmosphere can be passed over test papers which indicate the presence and approximate concentration of the toxic gases, carbon monoxide and hydrogen sulphide.
J.-W. (Johnson-Williams, Limited)
M.S.A. (Mines Safety Appliance Co.)

The following general comparisons can be made between these four instruments.

Battery Equipment: The two U.C.C. models use interchangeable four-volt sulphuric acid wet batteries, which have to be recharged at periodic intervals and therefore necessitate battery charging facilities. The J.-W. and M.S.A. models both use a battery equipment of two No. 6 dry cells, which are, when worn out, replaced by new cells.

Safety of Operation: Inasmuch as the operation of these instruments depends on burning the gas contained in the unknown mixture, the problem must be met of avoiding ignition of this unknown mixture. All four instruments are protected by screens designed to prevent the propagation of flame to the outside. The U.C.C. "50C" model is not recommended, however, for use in atmosphere containing acetylene, hydrogen and hydrogen-carbon monoxide, nor the All Service model for use in mixtures of "hydrogen-oxygen, acetylene-oxygen and oxygen-inflammable gas"; the J.-W. flame arresters are not considered infallible when used with hydrogen or acetylene; the M.S.A. bulletin asserts that "the standard assembly of the M.S.A. instrument may be readily calibrated for manufactured city gas, blast furnace gas, coke oven gas, and other mixtures of carbon monoxide, hydrogen, methane and acetylene."

Field Usage: All four instruments can be used for any type of field work, either to prospect manhole atmospheres, pavement holes, or atmosphere spaces such as hollow walls or basements. The U.C.C. Model "50C" has the detector unit outside the body of the apparatus on the end of a 50-foot cord, so that this unit or "head" can be lowered into a manhole or otherwise introduced into the test space. An attachment is available, however, so that the unknown atmosphere can be aspirated into the detector head by suction through a tube. The U.C.C. "All Service" model and the J.-W. and M.S.A. models have a built-in detector unit so that the unknown atmosphere must be aspirated through a tube and into the instrument.

Service Recommendations: Each of these instruments has incorporated in it certain special and distinctive features which make it desirable for a special kind of work, and it is recommended that they all be investigated by the prospective purchaser to see which is most applicable to his needs. For instance, the most accurate instrument that can be used on the widest range of conditions may be the most sensitive and complicated and require the most careful servicing and therefore should only be used by a technically trained operator. The most rugged and "fool proof" instrument may be the heaviest and most cumbersome. A "standby" instrument that is relatively non-deteriorating and always ready for emergency service might prove very costly if in constant use because of the necessary battery and filament replacements.

2. Bureau of Mines Combustible Gas Detector: The apparatus in principle follows that used by Katz, Meiter and Bloomfield and described in Report of Investigations 2710, Bureau of Mines, October, 1925, pp. 20. An additional device was one for adding increments of combustible vapor or air so that mixtures below the lower explosive limit, or above the upper explosive limit and also mixtures low in oxygen could be detected. Details of the apparatus and its operation are given in the United States Bureau of Mines, Report of Investigation 3109, May 1931. The apparatus consists essentially of an explosion bomb, a spark plug in the bomb through which to ignite the mixture; a gauge for indicating when an explosion occurs; a tank of propane for enriching with combustible vapor the mixture being tested; a measuring chamber and an outlet. With this attachment the approximate amount of combustibles in a mixture which is not explosive may be determined; it also may be determined when the atmosphere is low in oxygen.

The apparatus merits consideration, since it has been used exclusively in a survey of gases in manholes by the Edison Electric Illuminating Co. of Boston during the years 1929-1931 inclusive.

3. Flame Safety Lamp—Suitable for Detecting Petroleum Vapor: The investigation under the title: "Are Flame Safety Lamps Suitable for Detecting Petroleum Vapors," was published in the United States Bureau of Mines Circular No. 6083, September 1928. Conclusions reveal, that while safety lamps, when correctly assembled and intact, will not ignite a mixture of gasoline and air, these lamps are not suitable for determination of inflammable vapor contents of the atmosphere in and around tanks, holders, etc. The lamp will give unmistakable evidence of the presence of an explosive mixture and will give satisfactory indication to a trained observer in vapor percentages of approximately half of the lower explosive limit. Below this limit the lamp decreases as a valuable detector, and at 0.3 per cent and lower the evidence is so small and difficult that it should not be depended on. The lamp, however, is of value in conjunction with the work of any other gas-indicating device, in that the lamp will give indications of atmospheres deficient in oxygen, that could not be detected by an ordinary indicator.

4. S. & M. (Short and Mason) Gas Leak Indicators: This instrument works on a diffusion principle, whereby any gas present in the suspected atmosphere will diffuse through a porous diaphragm and either raise or lower the pressure within the instrument (with respect to barometric pressure), according as the gas is above or below the specific gravity of air. Indication is made by a hand traveling over a graduated scale. The amount of deflection of this hand is roughly proportioned to the amount of gas present in the tested atmosphere. If a calibration is made by a known gas-air mixture the indications are roughly quantitative. The instrument is chiefly used to test pavement manholes, over which it can be directly placed.

CONCLUSIONS

The problem of establishing responsibility for damage occurring from explosion after the accident has taken place is so involved, so specific in each individual case that even trained gas engineers differ in their opinions regarding the best routine safety methods to follow in all cases.

All the experts, however, agree that the maximum knowledge of conditions prior to the explosion is vitally important in solving the problem of responsibility for damages resulting from explosions.

In most cases of explosion investigations, the gas utility will be the defendant, trying to prove that there are many other substances except its own commodity that form explosive mixtures with air, which are just as explosive and just as destructive. With the original, systematic and complete records of surveys prior to explosion on hand, the task of proving the responsibility for damage may be greatly simplified.

Finally, it may be said that from a personal safety viewpoint, the utility should be equipped with a complete set of reliable instruments which can readily be used in case of emergency to enable engineers and chemists to analyze thoroughly the cause and the nature of any explosion that may arise.

INVESTIGATION PROCEDURE ON APPLIANCES REPORTED TO GIVE OFF OXNOXIOUS FUMES*

Natural gas distributed throughout the country in place of manufactured gas, is considered one of the safest among the gaseous fuels, primarily because its composition does not include any of the poisonous constituents that we are accustomed to associate with manufactured gas such as carbon monoxide. Nevertheless, natural gas engineers are occasionally summoned to court, as experts, in the gas poisoning cases involving either suffocation or carbon monoxide poisoning.

Source of Carbon Monoxide

Carbon monoxide formation from the combustion of natural gas is not the fault of the gas but is attributed to one of the following causes:

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1. The faulty appliance or to an appliance improperly set or connected with insufficient or improper flues.
2. Ignorance of the consumer in an effort to get greater rates of gas flow than the appliance can burn efficiently.

Carbon Monoxide Test

As a gesture of good service at first, as a source of indispensable information concerning the operating characteristics of different appliances later on, and, finally, as a necessity for protection to the public and self-protection in lawsuits instituted against the gas company, the Los Angeles Gas and Electric Corp. adopted the following safety measure in dealing with "carbon monoxide" complaint cases.

"Carbon monoxide" complaint is generally received in the form of request to adjust an appliance which is causing headaches, dizziness and nausea. The consumer advises us of the symptoms of the carbon monoxide poisoning without direct reference to the suspected presence of carbon monoxide gas. It is an exceptional call for the consumer to specify the request to check "appliances for carbon monoxide."

The complaint call, be it from consumer or police department (in fatal cases) is answered by sending an expert on appliance adjustment to the premises, with the instructions to take two gas samples, one "before" and the other "after" any work on appliance has been done, into two separate rubber bags. Properly labelled or tagged bags are mailed through the Corporation's mail to the chemical laboratory. Test for carbon monoxide is usually made sometime during the day unless the bags are marked "rush". In the latter case the result of the test is obtained within an hour after the arrival of the bags. As a rule, gas samples are never kept in the bags over 24 hours, fearing the possibility of changing their compositions due to selective porosity of rubber to different gases. The necessity of the above precaution has not been determined, however, and still remains to be checked.

Laboratory Test Procedure

Out of the number of tests for carbon monoxide-in-air mixtures that are known at the present, our laboratory selected the procedure of determination by the pyrotannic acid method, developed by the Bureau of Mines. The method serves the requirements of the rapid and sensitive analysis very satisfactorily and the data obtained by it do not leave any doubt as to their validity. Since the description of the testing procedure and the apparatus required can be found in either the "Gas Chemist's Handbook" or in Bulletin 197, Bureau of Mines, United States Department of Commerce, it was considered unnecessary to repeat it in this paper.

Practice has shown that in the final laboratory report the concentrations below 0.01 per cent carbon monoxide in a gas mixture analyzed could be safely omitted for the following two reasons:

1. The sensitivity of the test or, rather, the perception of the color change at the concentration below 0.01 per cent is so uncertain, that the shade differentiation of the sample as compared to the blank may be as well attributed to the deficiency of oxygen or the presence of carbon dioxide in the sample tested, or to both of them, to justify the differentiation at all.

2. The Technical Paper 362, Bureau of Mines, Department of Commerce, 1925, states: "for ordinary conditions in the home, where the occupants may be exposed almost continually to this gas, the concentration of carbon monoxide in amounts greater than 0.01 per cent should not be allowed."

Appliances that do not respond to the first adjustment and show presence of carbon monoxide in the "after adjustment" bag sample, are checked over by the expert on his second visit. The second "after adjustment" bag sample is tested and if it still indicates carbon monoxide above 0.01 per cent present, the appliance is generally taken to the shop for major changes in air ports and burner sizes.

With the large number of samples coming in daily during the winter months, the problem of blood supply is quite adequately met by obtaining it in the nearby packing house, diluting it there in 1:20 ratios with distilled water, and preserving it on ice. Samples of blood kept on ice for two days were found quite satisfactory for the purpose of analysis.

INVESTIGATING EXPLOSIONS*

An ideal arrangement for the purpose of gathering evidence at the scene of an explosion is to pair an investigator having legal training with one having a technical training. The reason for this is obvious: the technical man views the effects of the explosion and attempts to deduce the probable origin and cause; the legal man determines from the probable cause the extent of the utility's responsibility and estimates the value of the damage. Both investigators, in collecting their data, must not overlook the value of statements by reliable witnesses but if they are wise they will see to it that good photographs are taken of the interesting aspects of the case and filed for future reference.

Despite much similiarity in all cases of explosions, each case has certain peculiarities all its own; therefore, it is quite difficult to outline any standard procedure for their investigation. Some general observations on how explosions sometimes occur and the manner in which they are likely to exert their destructive forces may be of interest.

In the most common type of gas-burning appliances a part of the air necessary for proper combustion is injected ahead of the flame. The remainder of the required air is obtained from the atmosphere surrounding the flame. In contrast with this, the gas before an explosion is mixed with the entire amount of air required for combustion before ignition takes place. In the first case flame propagation takes place with a comparatively uniform slow movement. The appliance, if properly designed, creates a balanced condition between the rate of efflux of the gas and the rate of flame propagation. In an explosion no such condition of equilibrium exists and the flame propagates in all directions from the point of ignition. If an explosive mixture were not confined in some sort of a container, what we regard as an explosion would not be greatly different from lighting a gas appliance. In reality, an explosion is merely combustion with restricted expansion. The same thing is true of almost any of the common explosive media. For example, a small quantity of gunpowder can be lighted with a match and it will burn with a comparatively slow and utterly harmless flame; confine this gunpowder and a terrific explosion takes place. The same thing is true of a natural or manufactured gas on a less violent scale.

In discussing gas explosions, like discussing gas measurement, technical accuracy requires that conditions of temperature and pressure be carefully specified. For purposes of this paper, let us consider only a natural gas at atmospheric pressure, mixed with air in the proportion necessary to give maximum explosiveness. Such an explosive mixture, if ignited in a glass tube and photographed under proper conditions, will show that an explosion is merely a propagation of various waves. In order of their occurrence these waves are: compression wave, detonation wave, retonation wave, reflection wave and collision wave.

In order to convey some idea of the comparative speeds of these various types of waves, the following is submitted for an equimolecular mixture of acetylene and oxygen:

Wave Speeds

1.	Compression waves	1050 ft. per sec. (approx.)
2.	Collision waves	6726 ft. per sec.
3.	Reflection waves	7382 ft. per sec.
4.	Retonation waves	7546 ft. per sec.
5.	Detonation waves	9810 ft. per sec.
6.	Normal flame propagation	11 ft. per sec. (approx.)

In a so-called high explosive, T.N.T. for an example, the detonation wave travels with a velocity of 21,637 feet per second.

It is not difficult to see from the foregoing figures that these wave velocities are a rough index of their destructive powers in an explosion. Accordingly, we would expect that a compression wave would be much less destructive than a detonation wave in the same mixture. Similarly, we would expect a detonation wave in T.N.T. to be considerably more violent than one in an acetylene-oxygen mixture. In "Flame and Combustion in Gases", by Bone and Townsend, Page 164, will be found the following statement regarding explosion waves: "in the explosion wave an abrupt change in chemical conditions is propagated which generates an enormous force as it passes through each successive layer of the medium". Investigators have determined this force with considerable accuracy by shattering glass tubes of known mechanical strength. Forces upward of 120 atmospheres or about 1,800 pounds to the square inch were found in some instances.

The literature does not seem to disclose any accurate determinations of the forces in natural gas explosions but from what is known of Methane and Ethane explosion waves, it is fairly safe to assume that a natural gas-air mixture exploded in a closed container, when detonation does not take place, will generate a pressure of about 100 pounds per square inch, and when detonation does take place, will generate a pressure of about 1,000 pounds per square inch. So it is readily comprehended why natural gas can do considerable damage to a building, for the floor and walls of the average building are designed to withstand a pressure of only about 300 pounds per square foot or 2.1 pounds per square inch.

An investigator sent to the scene of an explosion can be almost certain, even prior to his arrival at the scene of the explosion, that he will not have to deal with a case of detonation. As previously stated, ordinary floors and walls will fail far below the pressures necessary to detonate a natural gas-air mixture, so only waves that must ordinarily be considered are the compression waves or, more appropriately, expansion waves since they result from the heat of the combustion. Excellent proof of this assertion was evidenced in a case which occurred recently. The layout of the house where this explosion occurred was roughly as shown in Fig. 1.

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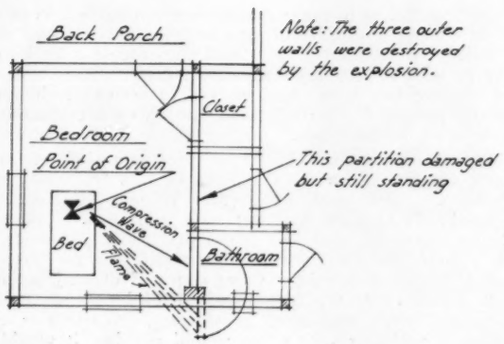


Fig. 1.

The conditions were as follows: A man retired to his bedroom and, according to his confession, chinked all the doors and windows and with suicidal intent turned on the gas. After the gas had been escaping from an open hose cock for some time, he decided on a last cigarette. Sitting in bed, he struck a match. The moment the match was lit the explosive gas-air mixture in the room ignited and an explosion followed which completely demolished the bedroom. Investigation disclosed that the point of ignition was near the center of the bedroom, and that the door leading from the bathroom to the bedroom was closed and locked at the time of the explosion. This was deduced from the fact that both the catch and the lock on the bathroom door were broken off flush with the edge of the door and the pieces were found in the debris on the floor. One would ordinarily think that if the gas-air mixture in the room were ignited somewhere near the center of the room and the bathroom door were closed at the time of the explosion, the side of the bathroom door facing the origin of the explosion would be charred and blistered by the heat of the flame. Yet, strangely enough, it was the side of the door facing the bathroom that actually showed such evidence. An explanation of this strange and apparently mysterious happening is that damage in this case was done by the compression waves which preceded the flame front. The waves exerting their pressure simultaneously upon the bathroom door broke the lock and caused the door to swing on its hinges through an arc of 180 degrees. With the outside walls gone, it was possible for the bathroom door to do so. When the door had swung into the new position as shown by the dotted lines in Fig. 1, the flame front had had time to reach it with the result that the paint was blistered on the side of the door which faced away from the explosion at the moment of ignition.

From this analysis it seems permissible to infer that the damage, in this case at least, was done by the compression waves that precede the flame front or, in other words, as a result of direct volumetric expansion due to the heat. If the walls of this room had possessed sufficient strength to withstand the pressure of the compression waves, and allowed them to rebound so that detonation could have taken place, it would have been altogether probable that the adjoining dwellings for some distance from this explosion would also have been damaged.

If we accept as true the assumption that practically all gas explosions exert a destructive force only as a result of compression waves, then we have a ready means of comparing gas explosions with other types of explosions. For example: a blasting explosion such as dynamite has very different characteristics as compared to a gas explosion. The principal differences are two in number. First: since a high explosive does its damage as a result of detonation, it is usually found that that which tends to resist the force of the explosion is damaged to the greatest extent. To illustrate this, a charge of dynamite set off while laying as a loose mass on a concrete floor is quite likely to break the floor but may not necessarily damage the walls or ceiling. Second: the speed with which a high explosive exerts its pressure does not allow sufficient time to raise the temperature of easily combustible material to its ignition point. An approved blasting explosive for use in mining operations must possess the property of radiating its heat so fast that if discharged in an atmosphere of 5.5 per cent methane, it will not ignite the gas.

It is evident that the two foregoing differences make it possible to distinguish, in a great many cases, between a gas explosion and an explosion resulting from a bombing or the like. For example, in another case which occurred recently, there was a bedroom where a bomb had been exploded. The mattress of the bed in this room was so damaged that the entire interior of the room was covered with a very fine cotton "fuzz" from the stuffing material. Strange as it may seem, the floor of this room was completely shattered while the walls were left standing and comparatively intact. If this had been a gas explosion the floor would have most likely been undamaged while the walls would have been taken out. Also, a fire would most certainly have resulted from the burning of the small tufts of cotton.

A third type of explosion is one resulting from a ruptured steam boiler or some other kind of pressure equipment which has failed due to overloading or some other cause. This kind of an explosion is usually easy to diagnose because the damaged equipment can usually be found and identified. For example, in a case which occurred about two years ago, a domestic hot water tank exploded due to excessive steam pressure, causing terrific damage. The tank of the heater was finally located some hundred yards distant protruding from the side of the home of one of the neighbors. Anyone examining the tank, after it had been recovered, would have had not the slightest doubt as to the origin and cause of this explosion.

Although the three examples cited are specific cases, yet, it is believed that they are representative of the usual run of explosions encountered ordinarily. The remarks in connection with each case are not intended to be a complete analysis but are merely hints as to what the investigator should look for in order to build up a presentable case in the event civil action is brought against the utility. For reasons of economy the many photographs in connection with the examples cited were omitted.

AUTOMATIC GAS SHUT-OFF VALVES*

A quick-closing, heat actuated and manually operated gas shut-off valve has been advocated by certain interested parties who have petitioned the City of Los Angeles to pass an ordinance making the installation of such valves compulsory on many kinds of gas-burning equipment.

We do not know what arguments these interested parties have presented to the city in support of their scheme, but we desire to present the following data both for and against this proposal which we have gathered from numerous sources, but principally from the transcript of Case No. 3181 before the California Railroad Commission, which pertained to the installation of a similar shut-off valve on all gas services throughout the State.

The primary purpose of the automatic valve is to protect life and property in case of fire. This is to be accomplished in two major ways: by shutting off the gas supply in the fire zone and preventing the increased propagation of the flames by the addition of explosive and inflammable material; and by preventing any faulty and improperly operated gas appliances from starting fires, the automatic feature of the valve being actuated by a temperature of 160 to 170 degrees F., whereas the normal ignition temperature of drapes, wallpaper, floors, rugs, etc., would be substantially higher.

Both of these claims are true in a restricted sense, but the hazards against which they are purported to be a safeguard are greatly exaggerated. The quantity of gas fed to an incipient blaze by the ordinary gas appliance would seldom aid the spread of flames to any great extent and would not render the fire any more difficult of extinguishment, except in rare cases. In the exceptional cases the firemen could easily control the gas supply by operating the main service supply shut-off valve which is required by law to be placed in an easily accessible location. The likelihood of a fire being started by a gas appliance either through faulty adjustment or mismanagement is exceedingly remote.

According to the testimonies of a number of fire chiefs in the case mentioned, Case No. 3181, it was brought out that it was rarely necessary to shut the gas off in cases of fire; therefore, if it is seldom necessary to shut off the entire gas supply, it would appear to be considerably less important to shut off the supply to one or more appliances.

Of the several types of automatic shut-off valves which we have been able to examine, the least objectionable is open to the criticism that it is so designed as to require a stuffing-box to prevent gas leakage around the stem. Due to certain inherent qualities in the natural gas being supplied to this community, all stuffing boxes containing packing are prone to develop leakage in service, unless the packing is compressed around the stems to a high degree. In this type of valve it is impossible to tighten the gland beyond a certain slight amount or the internal spring will lack the power to automatically close the valve when the fusible portion of the valve melts.

It is very possible, therefore, that even this least objectionable automatic valve constitutes a greater fire, explosion and asphyxiation hazard in itself than that which it is designed to prevent.

There was no competent testimony introduced in Case No. 3181 to show that an automatic gas shut-off valve had ever been successfully and satisfactorily employed. It was, however, brought out that the State of Massachusetts for some months past has had a law

*Submitted by Norman L. Hoff, Los Angeles Gas and Electric Corp.

making the installation of such valves on the service supply line compulsory. The time is too short to profit by their experience. No municipality thus far has seen fit to pass ordinances requiring their installation, insofar as we have been able to determine.

The State of California, through its Railroad Commission, has just recently denied the need for such a contrivance on gas services. We are informed the National Fire Protection Association and the National Board of Fire Underwriters have adopted regulations in which automatic operation of these valves is not recommended.

In view of the opinion of the State regulatory commission and of these national bodies, together with the fact that a tremendous burden would be placed on the gas utilities and their customers which is not economically justifiable, action in this matter should only be taken after careful deliberation and a thorough scrutiny of the evidence for and against this idea.

CHECK VALVES OR PROTECTIVE EQUIPMENT ON LINES TO TORCHES USING OXYGEN UNDER PRESSURE*

Where high pressure oxygen is used in connection with gas, occasional explosions occur in the meter which at times are difficult to explain.

In some cases the meter is shattered by the force and the explosion constitutes a hazard in the form of possible personal injury, fire and property damage.

These instances occur where an oxygen-gas torch is in use, frequently in the case of battery repair shops and Neon sign shops. Gas is used at the normal delivery pressure, approximately 7 inches water column, and the oxygen is used under a pressure of 2 pounds to 7 pounds. When the oxygen is used under this excessive pressure, it is very likely the oxygen can back up into the house piping and into the meter, filling them with a combustible mixture. Now, is this mixture ignited from a chemical action, by a back-flash through the torch, or from some other reason?

Chemists tell us that when oxygen comes in contact with oil, a chemical action may take place resulting in spontaneous combustion. Gas meters generally contain a small quantity of oil, or at least the leather diaphragms are saturated with oil to preserve the diaphragms in a soft and pliable state. Is this oil responsible for this type of explosion?

A few months ago, Guy Corfield, chemist, Los Angeles Gas and Electric Corp., conducted a series of tests in our Laboratory, in an effort to determine if this spontaneous combustion could take place inside a meter.

Methods Used: (April, 1932)

1. Standard 5Lt meter, with neutral oil, as received from service.
2. Pacific 5Lt meter, no neutral oil, new diaphragm, regular "C" repair.
3. Sprague No. 1 meter, dry diaphragm, meter cleansed of oil, and grease.
4. Pacific 5Lt meter, new diaphragm, not oiled, meter cleansed of oil.

Procedure:

Each meter tested separately as follows: Placed on west side of Calorimeter Room at atmospheric temperature. Connected with natural gas and oxygen.

1. Purged with natural gas.
2. Oxygen slowly passed through until all gas purged out with oxygen.
3. Gas slowly passed through until all oxygen purged out with gas.
4. Operations 2 and 3 repeated two more times on each meter.

Results:

No explosion in any case.

At or about this time, Mr. Corfield corresponded with the United States Department of Commerce, Washington, D. C., and with the Testing Laboratory of the American Gas Association, Cleveland, Ohio, requesting information on this particular subject. The correspondence to the United States Department of Commerce was referred to the United States Bureau of Standards for reply, and briefly their reply was: "There is no way to safeguard the meter except to prevent the oxygen from passing back into the house piping", and it was their belief there were several commercial devices available for this purpose. They also stated it was their belief the amount of oxygen one would likely get into the meter would not be sufficient to cause spontaneous combustion, even though it came in contact with oil-saturated leather. They stated that for use in their own laboratory they "had constructed a back-pressure check valve with a very light aluminum disc". They also recommended placing two such check valves in series, if the pressure drop would permit, to insure against one valve not operating due to dirt or scale in the pipes.

The Bureau of Standards also forwarded some information, and test sheets, obtained from the Consolidated Gas and Electric Light and Power Co., Baltimore, Md., (Mr. Wilson, superintendent of distribution). It appears they met with difficulties in that meters were being destroyed, and had found that check valves were not reliable. Their laboratory test sheets revealed that the Oxweld gas seal and a No. 70 Robertshaw valve operated in conjunction with an Emco relief valve which released at 15 inches water column back pressure, were considered satisfactory. While this type of installation is probably very effective and positive, it would be an expensive set-up for this class of small consumers, and it is likely this class of consumer would resort to an acetylene-oxygen outfit.

We have experienced that there were no explosions where a swing-type gas check valve was installed at the outlet of the meter. Yet our laboratory tests have shown that this type of check valve is not positive against back-pressure, but apparently is sufficient to stop any back-fire into the meter.

It is our practice to refuse gas service to a consumer where an oxygen-gas torch is to be used until swing check valve is installed. When a torch is installed after the gas meter is turned on, it becomes mandatory that a check valve be installed. We have, on occasions, installed check valves for the consumer, labor for installation being gratis and the consumer paying for the cost of the valve.

The writer has made many investigations on explosions of this type, and it is his opinion these explosions are flash-backs, and not due to spontaneous combustion. It is felt that it would be of value to the gas industry to conduct a series of tests to prove this point conclusively.

*Submitted by E. M. Torrance, Los Angeles Gas and Electric Corp.

NEED FOR ENGINEERING DATA TO COMBAT UNSOUND LEGISLATION CONCERNING THE SAFETY OF GAS APPLIANCES*

The careful reader of the daily newspaper and the weekly and monthly current event periodicals will soon notice that there is today a strong tendency of politicians and others to attack the practices and policies of public utilities. The reader will also notice that these same interests are calling for laws and regulations to hold these utilities within limits they believe are necessary. If the public utility is to endure under these attacks, it must forestall them by careful studies of situations in advance, and by such consequent actions as will place the utility itself in a position of security, where attacks can have little or no foundation on which to exist. When it becomes necessary to pass laws holding people of groups of peoples within certain limits to protect others in the community, it is a reflection on the foresight and practices of the people or the group. A law once passed on a technical subject frequently becomes a hindrance, as processes in the industry are constantly being improved. A regulation passed today may be out of date tomorrow, as all growing industries are dynamic rather than static. A law once passed is difficult to alter, owing to the cumbersome machinery required to repeal it. In this situation is found an opportunity for the technical man to anticipate and, if necessary, guide legislation by careful and continuous study of the conditions as they are today.

Although the strict anticipation of legislation falls within the province of the Public Relations Department, it nevertheless is evident that the Technical Department is in a better position to understand the meaning of problems dealing with technical phases of the industry. The technical man should be in a well prepared position to recommend tested devices, as he is familiar with the new protective equipment and recent inventions. The Technical Department can emphasize the limits within which protection can be obtained and can guide legislation so that interests of all parties shall be given proper consideration. As the technical man has to live and work with any new legislation passed, he should be prepared to meet any situation that might arise regarding proposed legislation for the future.

Many existent conditions require attention. Explosions, asphyxiations due to gas heating appliances, and damages caused by failures in domestic hot water heating systems are only a few of the conditions from which municipalities are demanding protection. The technical man has here an excellent opportunity to make tests and inventions which will be of great value in building confidence and as guiding procedure for the good of the gas industry.

*Submitted by H. M. Sutherland, Los Angeles Gas and Electric Corp.

To illustrate what may be done along this line, the following resumé on the subject of Relief Valves and Boiler Safety for Domestic Hot Water Heating Systems is offered. It is evident to all that failures may and do occur in domestic hot water heating systems. An analysis of approximately 50 accidents reported on tank and thermo-storage water heaters showed that a small percentage was due to actual rupturing of the tank wall. The majority were due to delayed ignition or back-flash, and the failure of limed up heating elements. The small group of accidents due to actual rupturing of tanks includes, however, the most serious types of accidents, and everything to mitigate this trouble should be furthered. Another cause of serious trouble occasioned by the operation of domestic hot water heating systems, is that many meters of the Water Department have been damaged by the backing up of hot water from the hot water heating unit. The Water Department of the City of Los Angeles reports that during the past eight years 42,747 meters were removed for failure to operate due to being damaged by hot water. This is approximately 41 per cent of the total number of meters removed for all causes during this period. Due to the fact that the water companies are often municipally owned, complaints and recommendations originated by them carry considerable weight in influencing legislation.

In studies made on protecting domestic hot water heating systems, it has been found that safety pilots and proper education in their use, minimize the hazards of back-flashes; the requiring of the proper type and location of safety relief valves will do much to prevent actual rupturing of the tank. Accidents due to explosions and failure of limed up heating elements can be controlled by restricting the sale of these certain types of heating units. Dangerous conditions can be minimized by passing information on to manufacturers and to prospective owners. The determination of what is the proper type of safety relief to be used on a water tank is still under discussion. Similarly the question of protection of water meters is still being studied.

Relief valves now offered will afford protection against excessive pressures, dangerous temperatures and vacuum. A pressure relief valve and a temperature valve are both desirable on any hot water heating system. Vacuum relief valves are not so necessary, as most tanks are capable of withstanding a vacuum, and automatic protection from vacuum is provided in many systems by means of a relief hole in the cold water pipe. Pressure relief valves have been designed to relieve the hot water systems of excessive pressures that might be built up in case the gas burner was not turned off either manually or by thermostatic action. These pressures are built up in a so-called closed or tight system. Any system using a check valve, a pressure reducing valve or regulator would come under the classification of tight or closed systems. An open system may be converted into a closed one by the shutting off of a street valve necessitated by the occurrence of a plumbing leak or other trouble. Pressures may rise to high levels in a few minutes, long before the water has become appreciably hot in a closed system with all fixtures shut. This rapid increase is due to the expansion, practical non-compressibility of water, and the reaction of the walls of the enclosing tank. Curves have been plotted from data collected direct from laboratory experiments made to show pressure effects obtained by increasing the temperatures of water contained in a closed system. (See composite curve, Fig. 1.) These curves show that a pressure developed in a closed system reaches large amounts within a short temperature range. For example, in a closed welded container, 6 inches in diameter by 12 inches in length, a pressure of 275 pounds gauge was obtained over an initial starting pressure of 27 pounds gauge by raising the temperature about 30 degrees Fahrenheit above the initial starting temperature of approximately 90 degrees Fahrenheit.

There is, however, another situation which is apt to occur. An explosive condition may be developed below the pressure at which a pressure relief valve might be set. It might also be possible to produce steam in a hot water tank, should syphonage occur while the heater burner was still operating.

Accordingly, it becomes evident that a pressure relief valve should be supplemented by a temperature relief valve, if this condition is to be prevented. The temperature relief valve can also prevent steaming water at the fixtures, depending on the temperature at which it is set. It may also serve as an additional safeguard in the case the pressure relief valve sticks. It will not relieve a closed system of excessive pressure resulting from expansion of water as previously noted. It may prevent explosions due to flashing of hot water into steam. The temperature relief valve, if properly adjusted, can also act as protection to water meters against damage from hot water. It is evident that a pressure relief valve and a temperature relief valve are desirable on water heating systems. The studies of the American Gas Association and the studies of individual companies show that there are many types of both pressure and temperature relief valves. A description and discussion of valves alone would form a good sized report in itself.

The locating of the pressure and the temperature valves is also a

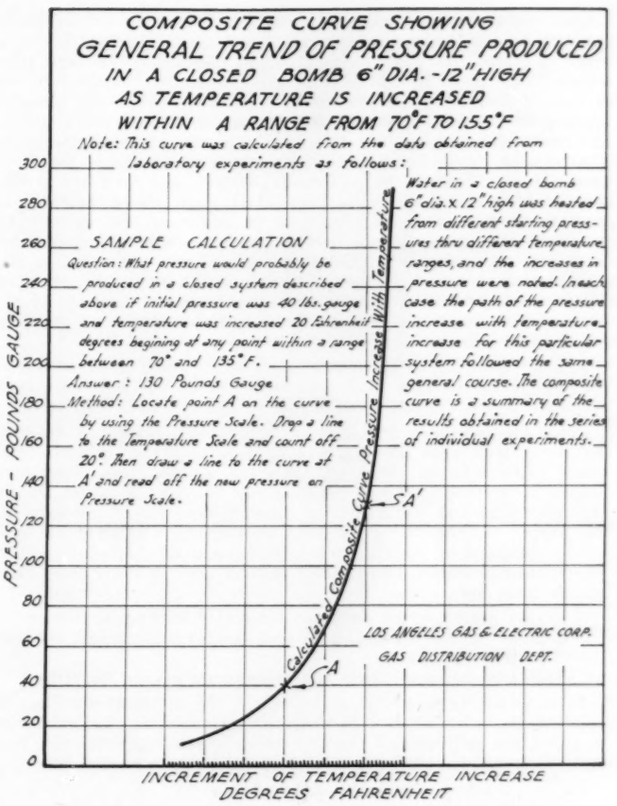

COMPOSITE CURVE SHOWING
GENERAL TREND OF PRESSURE PRODUCED
IN A CLOSED BOMB 6" DIA.-12" HIGH
AS TEMPERATURE IS INCREASED
WITHIN A RANGE FROM 70°F TO 155°F
Note: This curve was calculated from the data obtained from laboratory experiments as follows:
Water in a closed bomb 6" dia. x 12" high was heated from different starting pressures thru different temperature ranges, and the increases in pressure were noted. In each case the path of the pressure increase with temperature increase for this particular system followed the same general course. The composite curve is a summary of the results obtained in the series of individual experiments.
SAMPLE CALCULATION
Question: What pressure would probably be produced in a closed system described above if initial pressure was 40 lbs. gauge and temperature was increased 20 fahrenheit degrees begining at any point within a range between 70° and 135°F.
Answer: 130 Pounds Gauge
Method: Locate point A on the curve by using the Pressure Scale. Drop a line to the Temperature Scale and count off 20°. Then draw a line to the curve at A' and read off the new pressure on Pressure Scale.
Calculated Composite Curve Pressure Increase With Temperature
SA'
SA
LOS ANGELES GAS & ELECTRIC CORP.
GAS DISTRIBUTION DEPT.
PRESSURE - POUNDS GAUGE
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
INCREMENT OF TEMPERATURE INCREASE
DEGREES FAHRENHEIT

Fig. 1.

matter of considerable importance as a factor in their most efficient performance. In the experiments conducted it was found the most advantageous to place the temperature relief valves in the water at the top of the tank where the water was hottest, and on account of the practical ease of installation at that location on existing installations. The pressure relief valves were installed near the cold water inlet on account of the effects of higher temperatures on the valve seat. From the data which have just been given it is evident that there are a great many angles to the subject of relief valves for domestic systems alone. There is still much work to be done on this subject. The technical man must start collecting and tabulating these data at the earliest possible time. He must then place the information before the parties interested prior to the time definite action is finally taken.

By examining the ordinances which have been proposed and some ordinances actually passed it may be noted that only part of the protection outlined above is actually provided.

In addition, ordinances passed may place a penalty on new installations as the ordinance is not usually retroactive. In this particular period such legislation may retard the sale of new equipment intended to replace the old or obsolete devices.

A situation presenting some of the difficulties mentioned is developing at this time in the case of the heat-actuated shut-off valves, designed to minimize fire hazards. The Pacific Coast Gas Association in a letter dated February 2, 1933, to Association members, points out that a forceful effort is being made by "interests" selling the heat actuated shut-off valves to minimize fire hazards, to make their use compulsory in Pacific Coast localities. The Association states that a law to that effect has already been passed in the State of Massachusetts, which requires that an automatic device, designed to prevent or retard the escape of gas in case of fire, be attached to the intake pipe leading to the meter. It further adds that the "gas companies are complying with the law and expect it will take about nine years to complete making installations, and that both the companies and the Department of Public Utilities consider it to be a pernicious law and expect it to be repealed in a year or so." The Pacific Coast Gas Association makes the further addition that investigation shows gas rarely introduces a fire hazard which these valves would mitigate, and tests on many of the valves show them to be unreliable in their action and a detriment to gas service. The Association possesses a file of additional information which is available if legislation is proposed in the territory served. In the case of the heat-actuated shut-off valve to minimized fire hazards as reported by the Pacific

Coast Gas Association, an example is found wherein all the points outlined in this paper are illustrated. A forceful effort is being made to make the use of these valves compulsory—a legislation which in the main is beneficial to the "interests." If the interests succeed in promoting the passage of legislation which does not give the expected protection, a hazard is placed on both the company and the public. The public does not receive the expected protection. The company is confronted with an added expense and is hampered until the condition can be undone. The technical man has a difficult situation with which to live. Therefore, the technical man must make tests and investigations in advance, and present his results to the proper parties. The results so obtained may serve to guide any proposed legislation. They can place before the public a true picture of the protection which might be afforded. They can, furthermore, show that the company itself is vitally interested in proper use, and cautious in the utilization of the service which it sells.

Another field for study, which is of prime importance, is that of the control of the sale and designation of the proper safeguards necessary in the utilization of domestic space heating equipment.

From the examples which have been given, it should be clear that there is a need for engineering data to properly combat unsound legislation on technical subjects. Careful tests and their proper tabulation, and the building up of reference files on the safe operation and utilization of gas appliances are necessary for the proper understanding of these problems. The technical man is well qualified by training and experience to do this work. Three outstanding problems, facing the technical man of the Pacific Coast at this time, are:

Proper protection of domestic hot water heating appliances.
Control of the distribution and proper utilization of space heating appliances.
Problems connected with the elimination of fire hazards.

In these problems and in many others, the technical man has the opportunity to collect and to distribute information that will serve to guide the utilities and the consumers in seeking protection from conditions which now exist, or which might exist in the future.

UNDERGROUND VAULTS*

At the present time the Los Angeles Gas and Electric Corp. has approximately 133 concrete vaults in its distribution system. Each vault is equipped with a pressure reducing regulator and a large high pressure cylindrical dust trap which filters the incoming gas.

These underground vaults are ventilated by means of two 3-inch pipe conduits connected to a hollow ornamental gauge post, located in the parkway. The fresh air enters through the top of the gauge post, passes down through the hollow standard into the conduit which extends within 12 inches of the floor line in the vault. The outgoing or foul air is exhausted through another conduit, the opening of which begins near the ceiling of the vault and leads to the outside atmosphere by which this air escapes at the base of the gauge post.

This type of natural ventilation in some cases is none too satisfactory due to the small amount of circulated air. It is not always possible to set the gauge post near the vault and unless the air conduits are short, practically no air is circulated. Vaults having poor circulation soon become foul; moisture and slimy fungus cover the inside of the vault and the fittings, which increases corrosion. For this type it became necessary to install some type of forced ventilation in vaults having long air conduits.

For this purpose the Los Angeles Gas and Electric Corp. developed a ventilating fan, operating on the principle of a turbine, which has proven very satisfactory. It is designed to use the differential pressure across the high pressure gas regulator as a source of motive power. Fig. 1 shows its general appearance and the manner in which it is connected. The incoming gas, connected to the high pressure line coming into the vault, passes through a pressure control valve which operates the ventilating fan. This gas, in turn, enters the inlet of the fan through a nozzle directed at the tips of the vanes of the fan in the gas-tight compartment. From this compartment the gas leaves the outlet of the fan and flows into the low pressure line leaving the vault.

The control valve is specially designed to operate on various inlet pressures. This control valve is actuated by a diaphragm, lever and weight. Due to an exceptionally small diaphragm, the control-valve will operate on varying inlet pressures of 15 to 35 pounds. It also has a double valve which makes it possible to raise the transmission line pressure without affecting the r.p.m. of the ventilating fan. The double valve arrangement in addition to the setting of weights on the lever arm, makes it possible to operate the fan at peak hours only, thereby prolonging the life of the unit.

The fan unit itself consists of two compartments, each containing a fan. One of these compartments is gas-tight, a common shaft connecting both fans through a stuffing box. This shaft is lubricated through Alemite fittings. The impellor fan exhausts the foul air through a 3-inch vent which is connected to the outlet air conduit near the ceiling of the vault. The fan operates between 1,000 and 2,000 r.p.m., depending on the inlet gas pressure; displacing an average of 150 cubic feet of air per hour. Vaults that have such an installation are kept free from moisture and foul air during all seasons of the year.

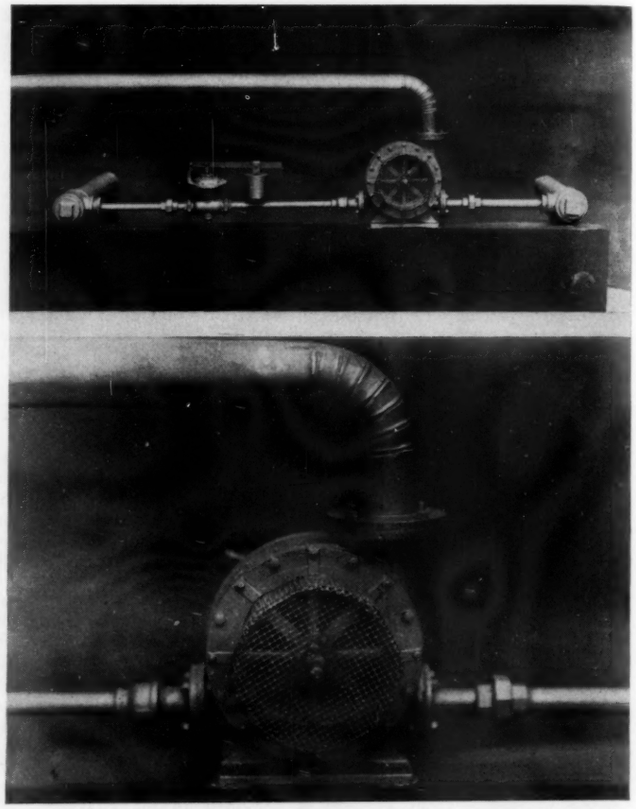


Fig. 1. Photographs illustrating a typical ventilating fan for underground vaults.

The Corporation has 24 of these units in operation, the first being installed November, 1926. The only necessary maintenance is the replacement of the shaft or the bearings which last from one and one-half to two years. The fans are lubricated every two weeks or during the routine inspection of the vault itself. The cost of one of these units installed, is approximately $118.

*Submitted by Hugo N. Johnson, Los Angeles Gas and Electric Corp.

BLOWING MAINS AND SERVICES FREE OF RUST*

Any public utility serving natural gas is confronted with rust problems, particularly in cases where manufactured gas was originally used. Attempts to cure rust troubles have not been entirely successful, but with the installation of various types of dust traps, etc., much progress has been made to retard or relieve rust conditions.

However, rust still accumulates in mains and services and when stoppages occur, it is necessary to clear them by means of high pressure gas or compressed air. When this must be done, the utility is confronted with a problem of removing the rust without causing complaints from those residing in the immediate vicinity due to clouds of rust being discharged into the atmosphere.

The Los Angeles Gas and Electric Corporation has developed a very efficient and simple dust trap for the purpose of removing rust from the mains, that eliminates both the dust and noise. Fig. 1 illustrates the principle on which it operates.

This dust pot consists of a 20-inch cylinder containing water to the depth of approximately 1 foot. A 2-inch connection for the introduction of the gas from the main to be cleaned, enters the cylinder at the water line, and discharges the gas under water.

*Submitted by Hugo N. Johnson, Los Angeles Gas and Electric Corp.

This removes most of the heavy rust which accumulates near the surface of the water and is drawn off at the overflow pipe. Fine dust particles which still remain in the gas after it leaves the water seal, are filtered out when the gas passes through a series of screens and burlap located near the top of the dust pot. A fine spray of water is directed on this baffle which keeps it moist and at the same time washes the rust down into the water at the bottom of the tank. The gas then passes out through the 4-inch outlet into the atmosphere, free from rust. The dust pot also has quite a muffling effect on the noise usually created when blowing a main.

The connections between the dust trap and the main are made with 2-inch pipe or a hose, depending on conditions in the field. The overflow or sludge presents a minor difficulty unless there is a catch basin nearby. The sludge has the appearance of very soft mud, and is hard to remove unless it can be disposed of before it overflows into the gutter. One method would be to pump it into a drip wagon and have it dumped elsewhere.

This portable dust trap has proven very successful in practice. In one case, when cleaning a 6-inch main, 1½ miles in length, it was operated for four hours, and the residents in the immediate vicinity were unaware of its operation.

The Los Angeles Gas and Electric Corporation has also constructed a dust trap to be used when clearing services of rust. Fig. 2 shows its construction. It consists of an outer cylinder constructed of heavy wire mesh, with a detachable top which permits the removal of the inner parts. At the other end, a ¾-inch pipe coupling is welded for attaching the hose connected to the service to be cleared. Inside of this mesh cylinder is a frame made of strap iron over which a burlap bag is placed. Before use, the burlap is always moistened to prevent as much rust as possible from being released into the surrounding atmosphere.

The use of this contrivance has practically eliminated any objection the consumer may have had to clearing rust from the service, which in most cases, comes up under the house and is in the driveway.

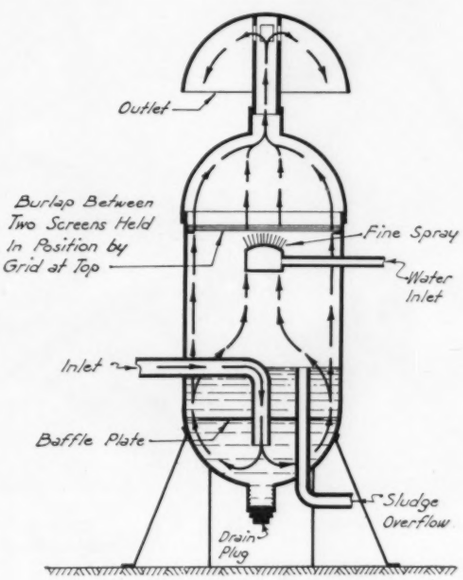


Fig. 1. Portable dust trap.

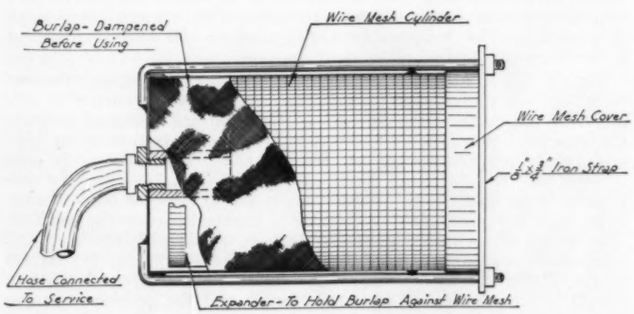

Burlap- Dampened Before Using
Wire Mesh Cylinder
Wire Mesh Cover
½"x¾" Iron Strap
Hose Connected To Service
Expander- To Hold Burlap Against Wire Mesh

Fig. 2. Dust trap for services.

CHANGING STOP COCKS UNDER PRESSURE†

A safety plug for changing high pressure service cocks, developed by the San Diego Consolidated Gas and Electric Co., has been successfully used by the Los Angeles Gas and Electric Corp., for approximately 12 months. Its effectiveness can best be illustrated

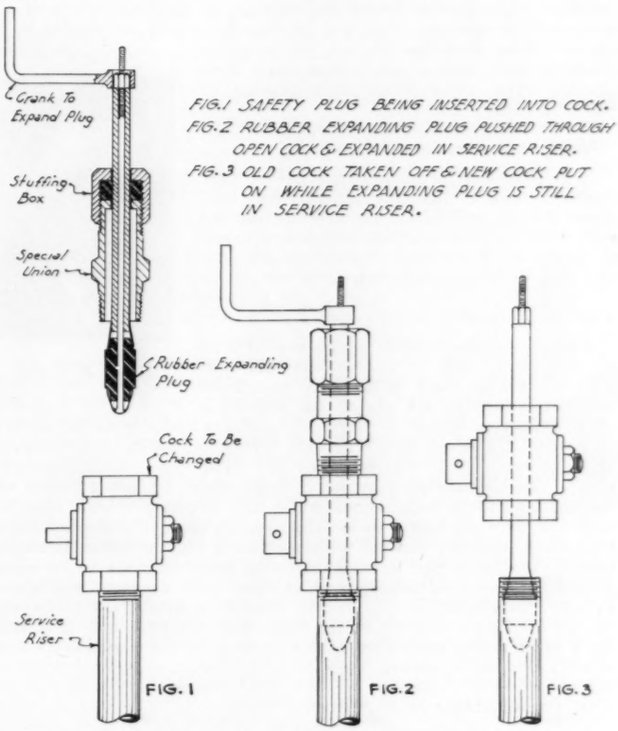


FIG. 1 SAFETY PLUG BEING INSERTED INTO COCK.
FIG. 2 RUBBER EXPANDING PLUG PUSHED THROUGH OPEN COCK & EXPANDED IN SERVICE RISER.
FIG. 3 OLD COCK TAKEN OFF & NEW COCK PUT ON WHILE EXPANDING PLUG IS STILL IN SERVICE RISER.

with the statement that prior to the adaptation of this device, it was necessary to have a helper with each emergency man so that the man bucking high pressure when changing a service cock would have protection in case difficulties were encountered; or, in the event a meterman encountered a defective service cock, it would be necessary to call for assistance.

The use of this device has made possible the elimination of the helper and permits high pressure service cocks to be changed by one man in safety, removing entirely any hazards of blowing gas.

Figs. 1, 2 and 3 show the operating procedure.

†Submitted by Hugo N. Johnson, Los Angeles Gas and Electric Corp.

Pipe Protection*

THE form of this report is modeled after last year's report. It consists for the most part of papers prepared by individual committee members. Rather than repeat any subject matter already published, a number of references are given, followed by a description of the additional data to be reported, descriptions of modifications of methods of tests, etc.

"GRAVEYARD" TEST FOR PIPE PROTECTION MATERIALS

Any organization using large quantities of pipe coating materials has submitted to it many samples which it is claimed will be effective for this purpose. Methods of tests which are quick and inexpensive and which subject all materials to the same conditions are desirable, so that a comparison of effectiveness can be made.

Preparation of Coating for Test

Nipples, 2 or 3 feet long, cut from 2-inch pipe are sandblasted. Any combination of pipe coating material (primers, hot or cold-applied coating, wrapper, outside shield, etc.) which is to be

*Committee Report: O. L. Wrestler, chairman, L. A. G. & E. Corp.; A. B. Allyne, So. Counties Gas Co.; M. T. Burton, So. Calif. Gas Co.; C. P. deJonge, San Diego Consolidated Gas & Elect. Co.; Chris. Goldcamp, San Diego Consolidated Gas & Elect. Co.; D. A. Hiskey, So. Calif. Gas Co.; H. J. Keeling, So. Counties Gas Co.; W. R. Schneider, P. G. & E. Co.; Clark Taylor, L. A. G. & E. Corp.; R. C. Terradell, L. A. G. & E. Corp.; B. A. Williamson, L. A. G. & E. Corp.; H. V. Buffington, L. A. G. & E. Corp.

tested is applied in the same manner as it is proposed to apply it in the field. The use of the apparatus shown in Fig. 1 facilitates application of hot-applied coatings. The shaft with nipple in place is removed from the trough to a frame where it can be rotated as the wrapper is applied. Primers and cold applied coatings are applied by brushing or dipping. The ends of the nipples should be protected to keep water from the inside of the pipe and to prevent moisture from getting under the coating at the ends where it is necessarily imperfect. This may be done by setting the nipples in a tin can filled with hot bitumen or by plugging the ends with wood stoppers and then dipping them in a hot-applied coating to build up a thick covering.

O. L. Wrestler

"Graveyard" Locations

It is proposed to make two types of preliminary tests so that the resistance to corrosive action and soil stress may be studied separately. Those coatings which are found to possess merit by these relatively quick tests can then be subjected to extensive tests.

Test for Resistance to Corrosive Action

Any convenient location which has little or no soil stress may be chosen for this test. The excavation may be a wide trench in which the nipples are placed parallel or a circular hole in which the nipples are placed radially as the spokes of a wheel. The soil should be very corrosive—Index (6-volt nipple and can test) of 10 or resistance (Shepard Rods) of 200 to 300 ohms. This condition may be brought about by the addition of sodium chloride. Sodium carbonate and sulphate should also be added if they are found in the distribution area. As the holes are back-filled, they are flooded with water. A high moisture is maintained throughout the test period. One hundred days is an ideal period for this preliminary test as most poor coatings will show evidence of failure in this time. The good coatings may be reburied for longer periods in the same holes. Additional salts will have to be added each time a hole is used, as the periodic wetting washes part of it away.

Test for Resistance to Soil Stress

A location in a heavy clay soil which is known to exert high soil stress is chosen for this test. Soils may be tested for this quality by a method described later in this report. The nipples should be buried in shallow holes—water being added as the hole is back-filled—and exhumed after the soil has thoroughly dried. In order that results may be comparable a "standard" coating of known resistance (to soil stress) should be included in each set of tests, also moisture determinations of the soil should be made at frequent intervals so that each set may be removed at a time when the soil has dried out to a definite moisture content.

Extensive Tests

Samples may be applied to lengths of operating lines or to a number of nipples. The test period should be relatively long, i.e. six months to two years. At the end of each successive period a different section of the length of line or a different nipple is uncovered and tested. "Graveyards" for these tests should be established in a number of known corrosive and high soil stress areas. A different nearby location is chosen for each set tested.

Testing

All samples are examined visually for cracks, etc. and tested for electrical conductance* (or resistance) before burial. Immediately after they are exhumed they are washed off with water, examined visually and tested for conductance* and pattern*. The coating is removed so that metal may be examined for rust and pits. The pattern test is not made at the beginning of the test because the high current required might break down the electrical resistance of the coating. If conductance tests are made on operating lines, the coating must be stripped off on both sides of the tested section. (See p. 526, P. C. G. A. Proceedings, 1931.)

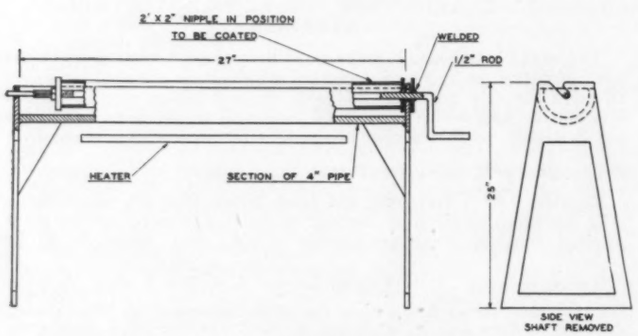


Fig. 1. Pipe coating applicator.

Discussion

It is possible by the tests described above to determine the relative effectiveness of coatings to protect pipe from underground corrosion. However, it must be remembered that there are certain considerations in connection with application, transportation and economy which will in some instances justify the selection of a less effective coating. One company which has made preliminary tests on a large number of samples has found that a large majority of them, including all but one cold-applied coating, are rejected as ineffective without further testing.

PROTECTION OF COUPLINGS

Couplings often are the cause of much concern because, on account of the fact that some of the parts are small, irregularly shaped, and made of different metals, they corrode sooner than the pipe. This condition can be corrected if the couplings are properly protected. Three methods of accomplishing this are suggested. Fig. 2 shows a pan which covers the lower half of the coupling. It is held tightly against the pipe by the clamps. Melted coating is poured over the top of the coupling, care being taken to add sufficient coating to completely fill the pan. The pan may then be removed and the excess coating returned to the pot. This gives a relatively thin coating. If this method is to be used in soils with high stress, a coating with high resistance to stress must be selected.

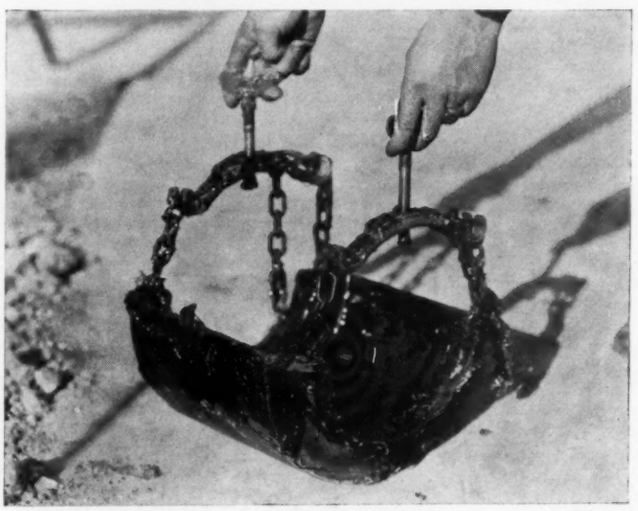


Fig. 2.

Fig. 3 shows a form which is to remain in place and act as a reinforcement to the hot-applied bitumen. The ends of the form are wooden discs which are slipped onto the pipe before the coupling is put on.The rest of the form is pipe wrapper which is tacked on the side of the wood discs so as to form a hollow cylinder with an opening along the top through which hot-applied coating is poured. (The wrapper is turned back in the figure to give a better view of the form.)

Fig. 4 illustrates a metallic housing for protecting Dresser couplings on underground steel pipe lines against corrosive elements of the earth. The San Diego Consolidated Gas and Electric Co. has used this type of protection for Dresser couplings on pipe sizes of 4-inch and larger for some years. The housing is constructed of No. 26 gauge sheet galvanized iron, built in two sections with flanged edges. These flanges are drilled for No. 10 stove bolts, and a ¼-inch felt is used as a gasket between the sections. The seams of each section are made with a crimping machine and afterwards brazed on the outer surface. The hole in the top section is for filling the encasement with bituminous compound. After the Dresser coupling is installed, tested and the primer coat ap-

*See p. 72. A.P.I. Production Bulletin No. 228 for description of these tests.

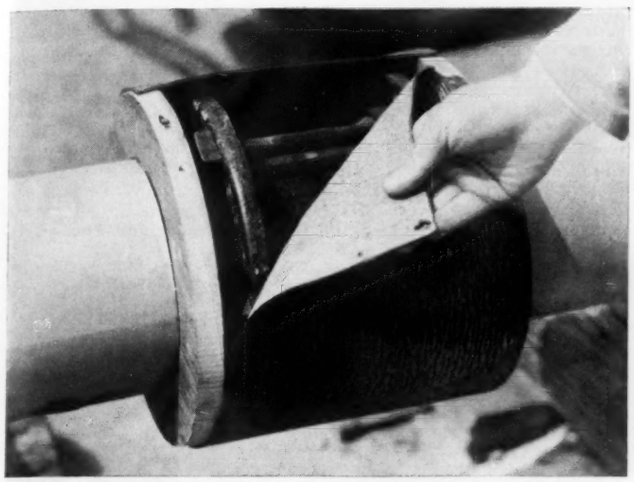


Fig. 3.

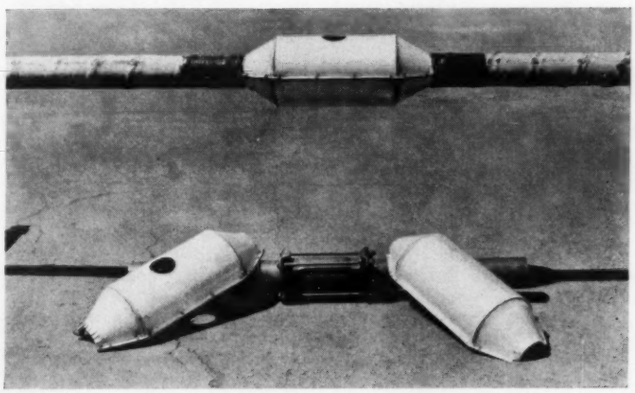


Fig. 4.

plied, protective wrapping is extended on the pipe to a point adjacent to the Dresser collars. This provision electrically insulates the housing from the pipe and provides a seal between housing ends and the pipe, preventing leakage of compounds at these points. Immediately, before the wrapping compound has cooled, the sections of the housing are installed and additional wrapping placed over the ends, further preventing compound leakage. The temperature of the compound with which the mold is filled should not exceed 180 degrees F., as a protection against possible injury to Dresser coupling gaskets.

CORROSION DATA

For the past two years this committee has been studying the rate of corrosion in different soils, but on account of the small amount of data available has not been very successful. Our study has been based on the assumption that corrosion may be measured by the depth of the deepest pit. Seven out of 10 pipe line men have indicated in their answers to a questionnaire sent out some time ago that they believe this is correct. Others would also take into account the number and width of the pits, etc. One thing is certain—a great deal of data is necessary to make a successful study. It is suggested that every operating company supply such field men as are capable of making accurate measurements with depth dauges, steel rules, calipers, and a form on which the following data may be recorded: Nominal size of (steel) pipe, maximum and minimum O.D., depth of deepest corrosion or pitting and depths of other deep corrosion or pitting, number of pits falling within various width limits (1/16 to ¼-inch, ¼ to ½-inch, etc.), and nipple and can index or Shepard rod resistance of the adjacent soil. Much of this data may be omitted if a pattern of the corrosion is made. This may be done by coating the cleaned pipe with printers' ink, using a well-inked printers' inking roller, then taking the impression on a piece of news print paper by pressing the paper on the inked pipe with a rubber roller.

A PROPOSED STANDARD ELECTRODE FOR ELECTROLYSIS TESTING*

The most pertinent questions that can arise in electrolysis investigations are: "Is the given underground pipe discharging current to the earth and if so, with what intensity?" All tests made of the potential difference existing between the pipe and other surface and sub-surface structures, even including that of the earth, furnish data along this line of a qualitative value only. It is current intensity, measured in terms of milli-amperes per square foot of pipe surface, which determines the rate of electrolytic decay. The current being directly proportional to the voltage and inversely proportional to the resistances of pipe covering and soil, it is evident that those measurements of potential differences which do not take into account these resistances give no quantitative values.

A reliable measurement of the discharge of current from a bare underground pipe is made by the well known McCollum Earth Current Meter method. A discharge of 0 to 0.5 milli-amperes per square foot is considered to be mild electrolysis; 0.5 to 3.0 milli-amperes, medium electrolysis; and 3.0 milli-amperes or more is considered heavy electrolysis.

The reservation of a bare underground pipe is made for if the test is made upon an insulated pipe line, either a misleading or a zero value may be recorded. For instance, if the insulation has broken down at small defects which would cover only a relatively small proportion of the entire pipe surface, an observed discharge of 0.5 milli-amperes per square foot might mean an intensely corrosive action at the local areas. This method does not take into account the concentrated attack of a small current upon an insulated pipe. Neither does it serve to measure upon an insulated pipe line a potential stress.

These limitations of the McCollum Earth Current Meter for measuring electrolysis upon insulated pipe are generally known by corrosion engineers. For instance, it is reported that W. R. Schneiders circumvents this difficulty in the following manner: He strips the insulation from the pipe, refills the excavation to a level of the mid-section of the pipe and then tests for leakage current with the McCollum apparatus in the refilled soil. As a supplementary test, he attaches a steel coupon to the pipe by an insulated wire, buries it in the refilled excavation, determines its loss of weight resulting from electrolysis by deducting from the total loss due to electrolysis and soil corrosion, the loss of weight of similar coupon which has been subjected to soil corrosion only. Tests made in this way involve considerable expense and time. (See "Corrosion Mitigation on Gas Lines of The Pacific Gas and Electric Co."—p. 408, P.C.G.A. Proceedings, 1932.)

Attention has been called to the erroneous conclusions that are likely to be drawn upon the rate of penetration of a small current, measured in terms of milli-amperes per square foot of pipe surface over the entire pipe surface in the case of an insulated pipe. This observation may be extended to include bare pipes, which have much of their bright surfaces covered by mill scale and rust.

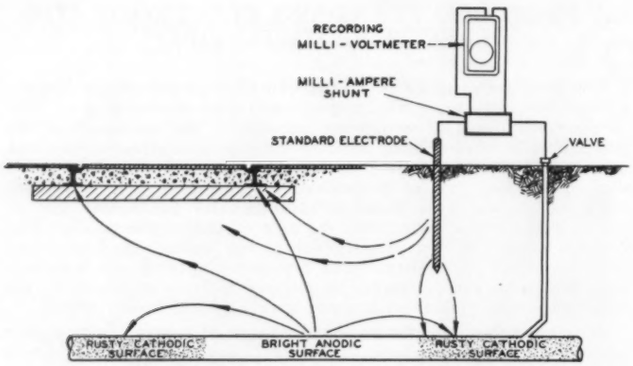
A pipe line engineer should be more concerned about the maximum intensity of current discharge occurring on the bright surfaces of the pipe than about the average intensity of current discharge on the whole pipe because the weight of a pipe in the scrap heap compares not unfavorably with its original weight. The maximum discharge will be concentrated on the bright areas because these are anodic to mill scale, rust, foundry films and to any other element that is likely to be found in a pipe line, except zinc. We are safe in assuming that any electrolysis resulting from current of any dynamic origin will be augmented by that of galvanic current.

This leads to the conclusion that while electrolysis measurements may be based upon the average intensity over the entire pipe surface, including that covered by good insulation, mill scale, rust, etc., it is preferable to base it upon the maximum intensity that is concentrated upon the bright iron, if, when and where it is exposed to the action of the soil.

It is proposed to standardize the pipe electrode (sand-blasted or sand-papered) having 0.5 square foot of surface exposed to the soil. The soil is wetted—so that the intensity of discharge will be maximum and equivalent to that which would be experienced during the wet season—and pressed firmly against the electrode. The electrode is connected through a recording milli-ammeter to any convenient part of the pipe such as valve, service riser, etc. Since the standard electrode is free of all rust and scale, it will be subjected to practically the same potential stress and soil conditions, existing for possible bright surfaces on the pipe.

Since the writer's test is an attempt to get a measure of the intensity of discharge from bright iron, where it is maximum, and not the average discharge for the entire surface, it is evident that a revision must be made upon this basis of what constitutes mild, medium and heavy electrolysis. The writer's observations would indicate that mild electrolysis lies within the limits of a dis-

*Submitted by B. A. Williamson, Los Angeles Gas and Electric Corp.



The electrode being bright and impressed with the same voltage should discharge galvanic and dynamic currents with about the same intensities as the bright pipe surfaces.

charge of 0 to 2.5 milli-amperes; medium, 2.5 to 7.5; and heavy, 7.5 or more. These values apply to the one-half square foot of the electrode exposed to the soil.

There are several criticisms which might be made to the method proposed in this paper. Heavy electrolysis may be indicated upon a perfectly insulated pipe. In this case, however, a high potential stress, which may be dangerous to the coating, is indicated. There are doubtless small errors due to polarization and difference in degree of aeration. Polarization of the potentials becomes steady after a few hours and the differences of aeration errors are common to all methods where soil is disturbed.

The use of the proposed "standard" bright iron electrode allows a differentiation between galvanic and dynamic leakage currents. The galvanic, including those of the "long line" variety, will be indicated during the early morning hours when the electric railway system is inoperative. Any electrolysis chargeable to leakage currents or any cathodic protection afforded by them, can be observed in the increased or decreased deflection which occurs during the period of street car operation. It is my observation that galvanic, and not leakage, current is responsible for most of the electrolysis, and that, in many instances, the leakage current is such as to mitigate galvanic corrosion.

To summarize, it is proposed to standardize, subject to the trial and approval of other electrolysis engineers, the bright iron electrode as a simpler, quicker, less expensive and, perhaps, a more satisfactory means of measuring electrolysis; in the case of bare pipes, or protected pipes with impaired insulation, it gives quantitative results; with non-impaired insulation, it gives qualitative values; it allows differential measurements of the galvanic and dynamic current components of electrolysis; finally, it makes possible 24-hour records.

Distribution Pressure Control*†

EFFECT OF PRESSURE ON LEAKAGE

IT IS not the intention of the Committee on Pressure Control to attempt to compete with any past, present, or future Committee on Unaccounted for Gas. It is necessary, however, for this Committee to have a good understanding of the effect of pressure on leakage so that it may calculate, or more accurately, estimate the savings effected by operating at reduced pressures.

Previous Tests

Underground leakage tests at Vancouver, Wash., on high pressure showed leakage to be proportional to the square root of the gauge pressure. (See Proceedings of the Pacific Coast Gas Association, Volume 16, 1925, Page 580.)

Larson, Portland Gas and Coke Co., showed leakage to be directly proportional to gauge pressure in underground lines. Line pressures between 1.7 inches and 13 inches were used. (See Proceedings of the Pacific Coast Gas Association, Volume 19, 1928, Page 459.)

Rawlins and Wosk showed leakage in transmission lines to be directly proportional to gauge pressure. Their report was quite complete, and also showed leakage from various types of coupled lines in open ditch, as well as rate of leakage through various types of fittings: circular drilled orifices, acid holes in pipe, cold chisel hole, large conical hole, copper tubing, lead wool porous plug, 2 inch pipe fittings, sandstone porous plugs. While tests are not given on the curves, their report shows the lead wool porous plug and the 2 inch pipe fittings to give leakage to atmosphere directly proportional to gauge pressure between zero and 150 pounds gauge pressure. (See Bureau of Mines Report 265, "Leakage from High Pressure Natural Gas Transmission Lines".)

H. S. Harris
Chairman

Mix, of Chicago, points out that underground leakage at low pressure is sometimes proportional to the square root of the gauge pressure and at other times approaches the gauge pressure. (See Proceedings of the American Gas Association, 1929, Page 1159.)

Renz, by the pressure drop method on underground leakage in small pipes (service pipes), showed leakage to be directly proportional to gauge pressure; minimum pressure used was 12 inches, maximum, 40 pounds. (See Proceedings of the Pacific Coast Gas Association, Volume 21, 1930, Page 524.)

Some work has also been done on flow of gases through broken solids:

C. C. Furnas: Flow of gas through beds of broken solids, Bureau of Mines Bulletin 307.

J. T. Storrow: The flow of air through small coals and other broken material; Translations Institute of Mining Engineers, Volume 55, 1917-18, PP. 313-317.

F. C. Zeisberg: Resistance of absorption tower packing to gas flow; Chemical and Metallurgical Engineering, Volume 21, 1919, P. 765.

F. C. Blake: The resistance of packing to fluid flow; Translations American Institute Chemical Engineering, Volume 14, 1922, PP. 415-421.

Burke and Plumber: Gas flow through packed columns; Industrial and Engineering Chemistry, Volume 20, 1928, P. 1196.

These latter works are not directly applicable to our problem of underground leakage in pipe lines, but there is sufficient information in them to indicate that underground leakage might *approach* a straight line flow directly proportional to gauge pressure. Simplifying the general equation for turbulent flow in conduits, C. C. Furnas expresses leakage as follows:

$$P_s = AXR^B$$

Where P_s = Pressure drop at standard conditions
A = Constant
R = Rate of flow
B = Constant exponent for each set of conditions.

The only thing that was found to affect the exponent "B" was the size of the passage, and if the exponent could be shown to be unity, the leakage curve would be directly proportional to the differential pressure which, in leakage from a pipe line, would be the gauge pressure.

Fig. 1, which is self-explanatory, is a reproduction from Page 13 of Bulletin 307 previously mentioned. From it, it appears logical that for a pipe line covered with soil, the exponent "B" would be very close to unity, and therefore, the leakage directly proportional to gauge pressure. In this case then, leakage should conform to Graham's Law which states that, for a given membrane, the linear velocity of the diffusing gas is directly proportional to the difference in partial pressure of the gas in question between the two sides of the membrane and to the square root of the absolute temperature of the gas, and inversely proportional to the thickness of the membrane and the square root of the molecular weight to the diffusing gas.

Test by Chairman

With a suitable container and equipment, pressure drops were obtained through various depths up to 6 inches of spherical solids, viz, 5/16 inch lead shot, BB shot, course sand, and fine sand. It was hoped from this that we might justify the assumptions which Larson used in proving mathematically that leakage was a straight line function of the gauge presure. He assumed the soil to be minute spheres, and by correct mathematics, equated the square root flow formula for orifice leakage above ground to a straight line flow for leakage below ground. Examination of these curves showed a flattening of the square root curve, but not sufficiently to prove the point.

*Committee Report: H. S. Harris, chairman, L. A. G. and E. Corp.; A. R. Bailey, Coast Counties G. and E. Co.; W. E. Genter, So. Counties Gas Co.; W. L. McKee, So. Counties Gas Co.; H. Keeling, So. Counties Gas Co.; Otto Goldkamp, San Diego Consol. G. and E. Co.; H. M. Goodro, So. Calif. Gas Co.; V. W. Harper, Portland Gas and Coke Co.; C. H. Ray, L. A. G. and E. Corp.; W. A. LaViolette, P. G. and E. Co.

†The words "pressure control" frequently referred to in this report mean the variation of the pressure over relatively short intervals of time by some means of control, either manual or automatic. They are not to be considered as meaning necessarily the control of a constant pressure, but rather that the system is under a scheduled control particularly adapted to that district.

Unfortunately, time did not permit continued tests with these same materials at greater depths. The next test was made with the same equipment using a well packed, damp, but not supersaturated, adobe soil at a depth of 30 inches. The curve on Fig. 2 shows the result as a straight line. A straight line was obtained, but not shown up to 6 inches of mercury column at which time boiling at the top of the soil was noticed and no further recording made. It will be noted that the line obtained runs through the point of origin, and thus shows in this case that leakage is directly porportional to gauge pressure. The dirt was removed and the test repeated without covering. Within experimental error, a curve was obtained equivalent to general orifice formula. This curve is on record but not shown.

The next test was made on a leaking, caulked lead, 12-inch cast iron joint. The pipe was cut off at both sides of the joint, end plates and a connection brazed on. After equilibrium was reached at each pressure, all air passing through the meter into the pipe was considered to have leaked through the joint. This test was run with ascending pressures, but as it can be conceived that the joint might increase in leakage due to its continually breaking away, the test was repeated with descending pressures. The curves are practically

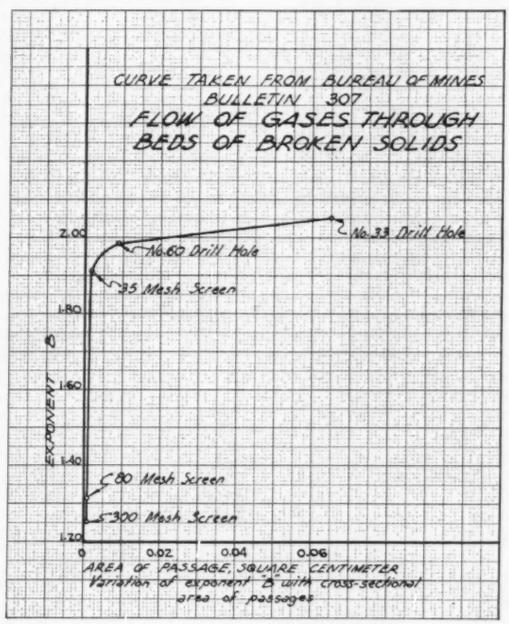

CURVE TAKEN FROM BUREAU OF MINES BULLETIN 307
FLOW OF GASES THROUGH BEDS OF BROKEN SOLIDS
No. 60 Drill Hole
No. 33 Drill Hole
35 Mesh Screen
80 Mesh Screen
300 Mesh Screen
EXPONENT n
AREA OF PASSAGE, SQUARE CENTIMETER
Variation of exponent n with cross-sectional area of passages

Fig. 1.

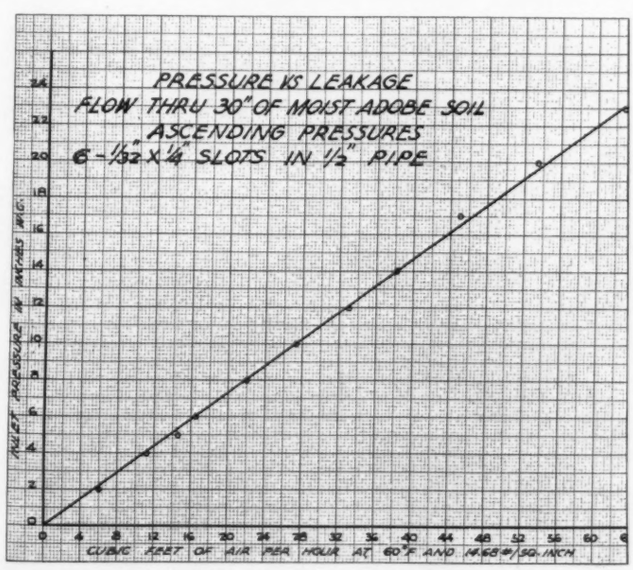

PRESSURE VS LEAKAGE
FLOW THRU 30" OF MOIST ADOBE SOIL
ASCENDING PRESSURES
6 - 1/32" X 1/4" SLOTS IN 1/2" PIPE
INLET PRESSURE IN INCHES W.C.
CUBIC FEET OF AIR PER HOUR AT 60°F AND 14.68#/SQ. INCH

Fig. 2.

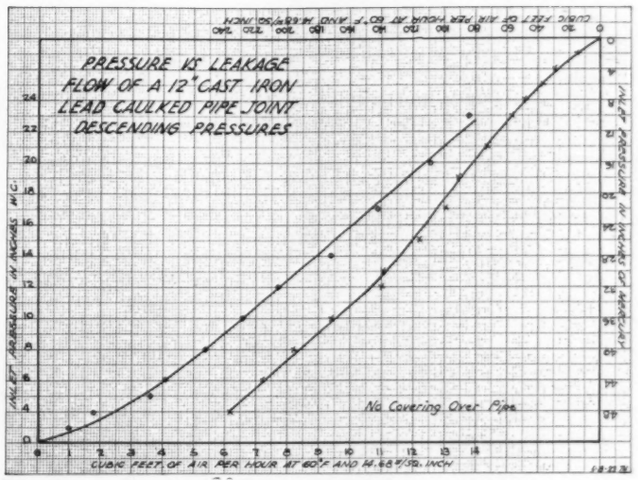

PRESSURE VS LEAKAGE
FLOW OF A 12" CAST IRON
LEAD CAULKED PIPE JOINT
DESCENDING PRESSURES
No Covering Over Pipe
INLET PRESSURE IN INCHES W.C.
INLET PRESSURE IN INCHES OF MERCURY
CUBIC FEET OF AIR PER HOUR AT 60°F AND 14.68#/SQ. INCH

Fig. 3.

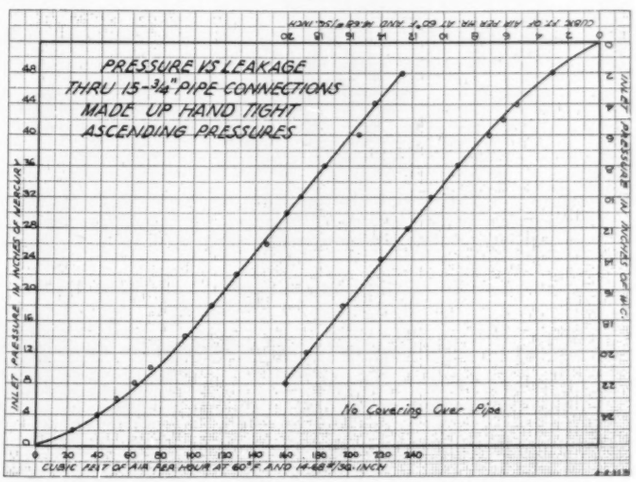

PRESSURE VS LEAKAGE
THRU 15 - 3/4" PIPE CONNECTIONS
MADE UP HAND TIGHT
ASCENDING PRESSURES
No Covering Over Pipe
INLET PRESSURE IN INCHES OF MERCURY
INLET PRESSURE IN INCHES OF W.C.
CUBIC FEET OF AIR PER HR. AT 60°F AND 14.68#/SQ. INCH

Fig. 4.

identical except for the slight hump in the high pressure curve shown. To avoid repetition of data and also to eliminate the doubt caused by ascending pressures, only that curve (Fig. 3) is shown.

Fig. 4 shows a pressure-leakage curve resulting from leakage through a short ¾-inch pipeline containing 15 threaded joints made up only handtight. By plotting acceptable flow (orifice flow) formulae on this graph, using any observed point as a basis, it may be seen that the results obtained in the experiment are much closer to a straight line curve than are the formulae, and it may be concluded from this that even leakage from fittings above ground at least *approach* a straight line function.

Fig.'s 5 and 6 show results obtained by burying two 2 x 24 inch sealed pipe nipples at depths of 24 and 48 inches respectively. Each nipple contained six drilled, but not calibrated 3/32 inch holes. Results obtained also show divergence from standard flow formulae.

Discussion of Available Data and Tests

Tests by the chairman indicate that the type of leakage encountered in a gas distribution system from both underground joint and corrosion leakage and overhead leakage from fittings is, *or approaches,* a curve directly proportional to the gauge pressure. The tests also show the phenomena of varying results as reported by the investigator Mix. In the majority of the tests, the chairman found his results to give a slight curve, but not a square root curve, with pressures up to 2, 3, or 4 inches water column. The curve was then a straight line to 2 or 3 pounds pressure, then taking a slight curve for a distance representing 1 or 2 pounds additional pressure, then again into a straight line. No explanation is given for the variations unless these particular points fall within a scope as mentioned in the works of Rawlins and Wosk, Bulletin 265, Page 31, in which they state that within zero and 300 pounds pressure, they found leakage to be directly proportional to gauge pressure except where leakage was very low. As a result of tests on

pipe representing an equivalent of 1,000 miles of 3-inch pipe, they set 150,000 cubic feet of gas per mile of 3-inch pipe as the demarcation point where, as the leakage decreased, the rate approaches an equation based on the square root of the gauge pressure.

There is a preponderance of evidence from all sources indicating that underground leakage in gas distribution systems is directly proportional to gauge pressure. The chairman agrees with this evidence by qualifying his own results. In the first place, in actual practice, except for plain sand soils, the soil would be more compact than in his own tests. Secondly, besides leaking through the earth, in actual practice, the gas is usually diverted by reason of a paving which causes the gas to travel a greater distance through the soil. In many cases, it is necessary to filter through a wet parkway or lawn. Thirdly, at the usual depth of a pipeline, in locations where there is at least a seasonal rain, the soil is quite damp. And, fourthly, when corrosion in a pipeline occurs, the products of corrosion stay around the pipe, causing the gas to *seep* out, even from the pipe. This is illustrated in Fig. 7 and Fig. 8. These show a 1-inch steel pipe which showed no visible hole until the corrosion product was chipped off with a knife. There is no question of this phenomenon with cast iron pipe.

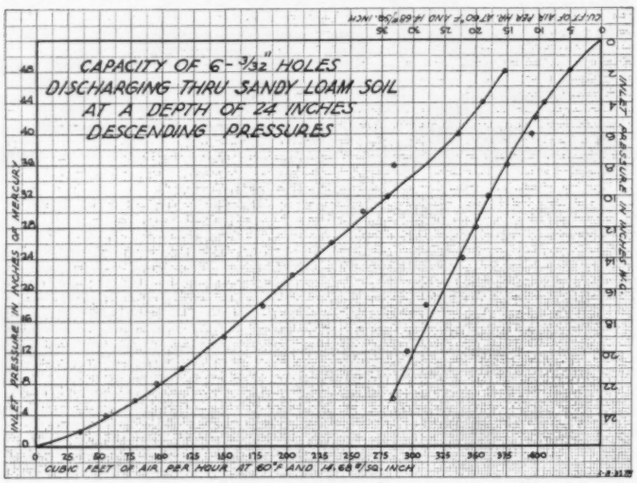

CAPACITY OF 6-3/32" HOLES
DISCHARGING THRU SANDY LOAM SOIL
AT A DEPTH OF 24 INCHES
DESCENDING PRESSURES
INLET PRESSURE IN INCHES OF MERCURY
CUBIC FEET OF AIR PER HOUR AT 60° F AND 14.68 #/SQ. INCH

Fig. 5.

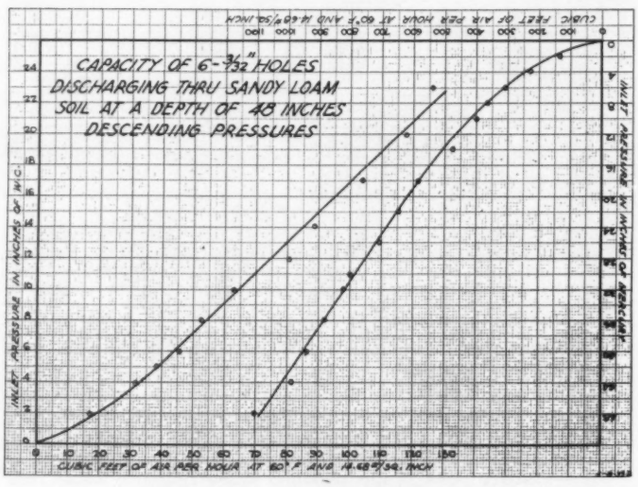

CAPACITY OF 6-3/32" HOLES
DISCHARGING THRU SANDY LOAM
SOIL AT A DEPTH OF 48 INCHES
DESCENDING PRESSURES
INLET PRESSURE IN INCHES OF MERCURY
CUBIC FEET OF AIR PER HOUR AT 60° F AND 14.68 #/SQ. INCH

Fig. 6.

From the foregoing, the chairman recommends the use of direct proportion to the gauge pressure for estimating costs on pressure control. As to overhead leakage, while the author found a divergence from a straight line curve for screwed fittings, blowing to atmosphere, Rawlins and Wosk reported a perfectly straight line. It seems doubtful that this type of leakage would be a straight line function in all cases. However, for boosts of more than a few inches, service regulators would be used, and therefore, pressure fluctuations would affect, if at all, the total overhead system leakage very slightly. Where necessary to calculate this change, the evidence shows that a curve directly proportional to gauge pressure would introduce less error than would a square root curve.

RELATION OF UNDERGROUND TO OVERHEAD LEAKAGE

The Southern Counties Gas Co. has made extensive tests on the relation of underground to overhead leakage. This work is entirely actual measurements of leakage in the field by isolating one or more streets at a time, shutting off the consumers, blanking the meters, and measuring the gas entering the main (loss of gas due to leakage) through a meter. The service is then blanked off at the stop cock ahead of the regulator (if there is a regulator) and another measurement taken. The difference between the two figures is assumer to be overhead leakage.

Table No. 1 shows a composite of all tests run at various main pressures, the test pressure being about the same as the usual operating pressure. Tests were run between 8 inches water column and 98 pounds pressure.

While a constant percentage overhead loss is expected on a theoretical basis due to service regulators, the uniformity of results obtained in the field tests is remarkable, and where no other information is available, the use of 15 per cent as an average figure for overhead leakage is recommended. Assuming each pipe to be the same age and in the same soil, we would expect the cubic feet loss per month per foot of main to increase as a direct proportion to the gauge pressure. Table No. 1 does not show this relationship and, in fact, shows much less leakage at higher pressures than at lower ones. From this we may conclude one or more of several things. Assuming the date of laying and the average soil conditions to be the same, either the higher pressure systems were better designed and more care taken in the installation, or more maintenance work had been done in the high pressure system.

Inasmuch as there is usually more hazard connected with leakage from a high pressure system, it is quite possible that more maintenance would be required. Therefore, when designing a system, we cannot necessarily conclude that the cost due to gas losses will be in direct proportion to the designed pressure as against some other pressure, for the cost of gas may be a secondary consideration as against the cost of maintenance.

ESTIMATE OF MONETARY LOSSES DUE TO EXCESSIVE PRESSURE

For purposes of estimation, we will assume that all systems are now being operated at the lowest possible pressure without additional capital expenditure. Due to increased load in some district, it then becomes necessary to either increase the pressure or lay additional mains, install governors, regulators, etc. Should a large consumer (industrial consumer) come on the system, demanding a higher pressure than is normally carried, it is necessary to induce the consumer to buy, or buy for the consumer, either a boosting machine or low pressure burners, or else to increase the pressure on the entire system, or to lay an additional high pressure main from some other source of supply.

Fig. 7.

Fig. 8.

TABLE NO. 1. LEAKAGE AT VARIOUS PRESSURES

Pressure Tested	Number Tests	Total Meters	Cu. Ft. Loss Per Month Per Meter	Feet Main	Cu. Ft. Loss Per Month Per Ft. Main	Mc. f. Per Monthly Leakage Underground	Under-ground Loss %	Mc. f. Per Monthly Leakage Overhead	Overhead Loss %	Mc. f. Per Month Leakage Total
L.P. 8"	137	5,568	80	181,561	14.0	2,559	85.2	447	14.8	3,006
Lbs. 1	19	359	25	19,164	32.4	622	98.6	9	1.4	631
Lbs. 1½	17	645	25	78,951	28.8	2,275	93.1	16	6.9	2,291
Lbs. 2	69	7,271	38	1,218,383	2.8	3,408	92.5	278	7.5	3,686
Lbs. 3	154	10,472	95	695,759	14.4	10,031	90.9	1,000	9.1	11,031
Lbs. 4	154	6,175	193	539,364	10.5	5,680	82.7	1,190	17.3	6,870
Lbs. 5	132	6,169	168	463,841	20.4	9,465	90.2	1,036	9.8	10,501
Lbs. 6	71	2,288	172	332,823	5.3	1,748	81.7	394	18.3	2,142
Lbs. 7	56	2,088	271	146,904	11.4	1,672	74.8	566	25.2	2,238
Lbs. 8	22	1,184	235	89,985	10.1	905	76.6	278	23.4	1,183
Lbs. 9	15	1,385	207	127,952	4.9	622	68.5	287	31.5	909
Lbs. 10	112	8,026	194	781,515	7.7	6,006	79.4	1,560	20.6	7,566
Lbs. 10½	11	1,062	137	51,450	3.3	168	53.6	146	46.4	314
Lbs. 13	12	434	159	68,506	4.1	283	80.4	69	19.6	352
Lbs. 15	17	1,353	230	152,722	11.4	1,746	84.9	311	15.1	2,057
Lbs. 20	2	185	459	50,790	1.5	76	47.3	85	52.7	161
Lbs. 25	91	3,375	395	517,768	16.2	8,411	86.3	1,334	13.7	9,745
Lbs. 30	5	216	218	89,426	2.2	198	80.9	47	19.1	245
Lbs. 40	2	62	161	13,765	3.2	44	81.5	10	18.5	54
Lbs. 44	1	102	294	6,070	8.4	51	63.0	30	37.0	81
Lbs. 50	5	283	555	95,898	4.3	417	72.7	157	27.3	574
Lbs. 98	1	—	—	16,500	3.3	55	100.0	—	—	55
TOTALS	1,105	58,702	158	5,739,097	9.8	56,442	85.9	9,250	14.1	65,692

Calculations involving the above are quite simple as to the loss and cost of gas at the present operating pressure as against any required additional pressure, but it should be remembered that overhead leakage on a high pressure system remains constant. This cost of lost gas should then be compared with the cost of additional mains, etc., and after consideration has been given to the possible increased hazard or maintenance cost due to increased pressures, the most economical and satisfactory method may be adopted.

METHODS AND COST OF PRESSURE CONTROL

The simple relation between pressure and leakage allows us to make a fair estimate of the monetary losses due to excessive pressure in the district. There is one point which has not been touched on—that the pressures might be left at a lower pressure during the off-peak hour if there were suitable and economical means of satisfactorily boosting the pressure during the peaks. Methods and costs of pressure boosting are included as a separate paper by H. J. Keeling of this Committee.

LIMITING FACTORS OF HIGH PRESSURE BOOSTING

In high pressure boosting the controlling factor is the lower limits rather than the higher. Except for additional unaccounted-for gas, it is doubtful if any system besides a lead caulked, cast iron pipe system, is so designed that it could not accommodate a pressure boost far in excess of what would be required. Even in the cast iron system, it may be possible to increase 25 pounds in pressure without increasing the size of the leaking orifices. (See explanation of Fig. 3). In reducing pressure for the off-peak hours, care should be taken that the pressure is reduced proportionally to the rate of flow so that the velocity in the mains will remain reasonably constant. This is particularly true of a system containing considerable rust and dirt in the mains. Care should also be taken to raise the pressure gradually and in the same proportion for the same reason. In *Western Gas,* August, 1931, Page 135, are 4 curves showing minimum expected capacities and performance of ¾-inch house type regulators. Unless all regulators in the system have means of compounding, these curves will give indication of how low the main line pressure may be reduced as far as the effect on the consumer's pressure is concerned.

Service and houselines may be calculated from standard formulae, except for increased friction due to bends, stopcocks, etc. Table No. 2 gives equivalent length of fittings from 1-inch up, as used by Los Angeles Gas and Electric Corp. By adding these figures to the pipe footage, a total length of equivalent pipe for calculating pressure drop can be obtained.

As a general rule, except in purely residential districts, the absolute minimum pressure will be governed by one or more industrial consumers. It is hoped that there is sufficient information contained within this report that one may calculate the economies of running additional pipeline or purchasing equipment for the consumer to strike a balance on minimum pressures.

LIMITING FACTORS OF LOW PRESSURE BOOSTING—PARTICULARLY SAFETY

As to service pipe and fittings for low pressure, the same calculations may be made as for high pressure. Low pressure boosting, however, differs from high pressure in that there are no service regulators, therefore, the volume of gas passing through the meter is affected as is also the performance of the consumer's appliances.

According to Boyle, gas at 8 inches pressure expands or contracts approximately ¼ per cent per inch of pressure, and as gas rates are usually based on quantities at atmospheric pressure, the higher the pressure on the meter, the greater the gas loss to the gas company.

With this thought in mind, tests were run to determine the lowest possible delivery pressure at the appliance. Appliances used in the test were both old and new, and some that were originally constructed to consume manufactured gas and adjusted to or reconstructed for the use of natural gas. It was observed in the tests that as the pressures were lowered, the capacity of top range burners was reduced as much as 9 per cent per inch of pressure, and in the larger burners the capacity was reduced approximately 12 per cent per inch. It was noted that flame characteristics changed considerably, in some cases, as the pressure was lowered while in others the change was barely visible. A pressure drop of 1 inch or possibly 2 inches would probably not be noticed by the consumer if gradually made over a long period of time, but an immediate drop of 9 per cent to 12 per cent capacity of the burners which is an equivalent B.t.u. loss, would no doubt cause a considerable number of poor pressure complaints.

In various space heaters the change in flame character was quite noticeable. As the pressure was lowered in the heaters, the flames became very lazy. It was also shown that in some heaters the capacity cannot be raised at 5 inches pressure to what it had been at 7 inches pressure by adjustment, as the flame would reach the top of the radiant due to slower entrainment of the necessary air with consequent lengthening of the flame. Samples of the products of combustion, however, showed no traces of carbon monoxide.

In the furnace tests, no difficulty was encountered except the lowering of the flame and the reduction of gas capacity. Experience in Southern California shows that the majority of homes have insufficient heating appliances, and so a further reduction in available B.t.u.'s would, no doubt, create many dissatisfied consumers.

From these tests and observations, it is apparent that a saving of approximately ¼ per cent per inch of pressure drop lowering would be inconsequential as compared to the loss in revenue due to the lessening of the capacity of the consumer's appliances. It must be appreciated, however, that the total loss would not amount to a

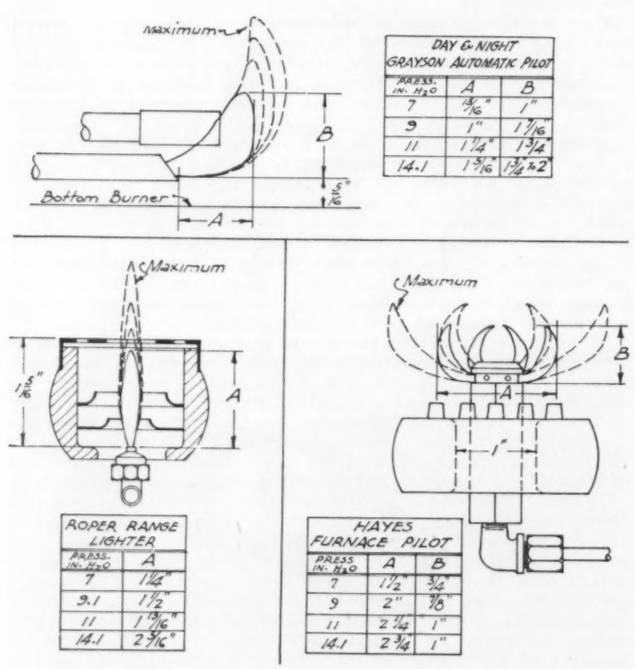
TABLE NO. 2. EQUIVALENT LENGTHS OF STANDARD FITTINGS IN FEET OF STRAIGHT PIPE

Fitting Combination	Diameter of Pipe 1-in.	1¼-in.	1½-in.	2-in.	3-in.	4-in.
1-in. Welded Tee and ¾-in. Orifice	10.8	52.1	125.7			
1-in. 2-Thread Tee	6.3	30.3	73.1			
1-in. 90 deg. Bend	0.5	2.4	5.9			
1-in. S. Bend	1.	4.8	11.7			
1-in. Gooseneck	2.	9.7	23.4			
1-in. Riser Bend	2.	9.7	23.4			
1-in. Mueller Cock	6.5	31.5	76.0			
¾-in. x 18-in. Ex. Hvy. Riser plus ¾-in. Mueller Cock	22.3	107.9	260.1			
⅞-in. Orifice through Pipe Wall	6.5	31.5	76.0			
1¼-in. Welded Tee and 1-in. Orifice	3.6	17.5	42.2	172.6		
1¼-in. 2-Thread Tee	2.2	10.5	25.3	103.5		
1¼-in. Mueller Cock	1.4	7.	16.9	69.0		
1¼-in. Orifice through Pipe Wall	1.6	8.	19.3	78.9		
1½-in. Welded Tee and 1-in. Orifice	3.5	16.8	40.5	165.6	1469.	
1½-in. 2-Thread Tee	1.1	5.4	13.	53.2	471.	
1½-in. Mueller Cock	0.6	2.7	6.5	26.6	236.	
2-in. Welded Tee and 1⅞-in. Orifice			4.0	17.	151.	663.
2-in. 2-Thread Tee			3.3	13.5	120.	526.
2-in. Mueller Cock			1.0	4.	35.	156.
2-in. B4-125 Nordstrom			1.8	7.5	66.	292.
1⅞-in. Orifice through Pipe Wall			3.7	15.	133.	585.
2⅝-in. Orifice through Pipe Wall				3.7	33.	145.
3⅝-in. Orifice through Pipe Wall					9.3	41.

Note: When pipe diameter is smaller or larger than fitting, it is assumed that a swedge is used.

straight 9 to 12 per cent as the consumer has each burner of each appliance at full capacity only during a portion of the actual cooking or heating time.

Tests were then run to determine the maximum boost that could be made on consumer's appliances without danger. These tests showed increases in consumption as the pressure was raised from 7 inches. At 12 inches pressure some of the burners did not function properly, tending to leave the burners, and when extinguished were very hard to relight. This is not a detriment because the consumer would take care of this by making his own adjustment by cutting down the gas valve. It was found, though, that above 14 inches, the flames, in some cases, left the burner in a manner that was dangerous if not watched. Capacities increased from 6 to 9 per cent per inch pressure increase.



DAY & NIGHT GRAYSON AUTOMATIC PILOT

PRESS. IN. H_2O	A	B
7	15/16"	1"
9	1"	1 7/16"
11	1 1/4"	1 3/4"
14.1	1 5/16"	1 3/4 to 2"

ROPER RANGE LIGHTER

PRESS. IN. H_2O	A
7	1¼"
9.1	1½"
11	1 15/16"
14.1	2 5/16"

HAYES FURNACE PILOT

PRESS. IN. H_2O	A	B
7	1½"	¾"
9	2"	⅞"
11	2 ¼"	1"
14.1	2 ¾"	1"

Fig. 9. Effect of an increase in pressure upon pilot flame.

Appliances tested in both the reducing pressure tests and the increasing pressure tests included two ranges, a water heater, gas-steam radiator, unit furnace, unit heater, two 10-radiant space heaters, and a 7-radiant manufactured gas heater reconstructed for the use of natural gas.

Tests were also made from a safety standpoint as to the effect of raising pressure on pilot lights. Three types of pilots were chosen:

1. Vertical type—single port giving upright flame.
2. Mushroom type—ports drilled horizontally.
3. Safety type—pilot flame heating thermal unit or element.

The following gives the approximate increase in flame size of the pilots at 14 inches when adjusted for 7 inches pressure:

Type of Pilot	Height	Width
Vertical	85%	.....
Mushroom	83%	33%
Safety	100%	40%

Fig. 9 shows dimensions of the pilots and flames at various pressures.

Test data on flame characteristics as mentioned in this report are available from the Los Angeles Gas and Electric Corp. They include test pressures, burner capacities, flame characteristics, and necessary adjustments to obtain same capacity as at 7 inches pressure. These data are not included in this report inasmuch as only maximum and minimum, without adjustments, are required for pressure control work.

SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

The Committee feels that it has touched upon sufficient information to allow a fair estimate of the desirability of pressure control to be made. It has concluded from previous and present tests, and offered a mathematical interpretation, that leakage of a nature encountered in gas distribution work, both underground and overhead, approaches sufficiently to a straight line function directly proportional to gauge pressure, that this relationship might be used with little error for calculating monetary losses due to loss of gas at excessive pressures. The Committee has also shown methods and costs of pressure control. From tests on consumers' appliances, it seems doubtful if pressure control is of much advantage for low pressure work, particularly where many furnaces and heaters are involved. It is quite possible, though, that a district with a high leakage factor would permit the lowering of pressures during the off-peak hours. From a safety standpoint, our tests have shown

that when operating at 7 inches running pressure at the appliances, pressures as low as 4 inches produced no carbon monoxide and pressures up to 14 inches were reasonably safe.

If future work is to be done on these subjects, your Committee recommends that the work be devoted to the operating costs and difficulties of pressure control. Difficulties encountered in maintaining a minimum pressure should make an excellent subject as far as future work is concerned, as well as the actual costs against actual savings of lower off-peak pressures. It is also recommended that field tests be run to determine if possible under what conditions pipe line leakage varies from a straight line function.

REMOTE CONTROL OF PRESSURE IN GAS DISTRIBUTION SYSTEMS*

In the electrical industry it has been common practice for some time to employ automatic and remotely controlled sub-stations in the transmission and distribution of energy. The circumstances accompanying the distribution of gas will probably never justify the use of such complicated apparatus in the gas industry. However, if a closer control of pressure results in higher operating efficiency, it is possible that the judicious use of telemetering and remote control will result in lowering the cost of distributing gas to the consumer.

On a low-pressure distribution system it is customary to use a weight-loaded regulator for controlling the pressure. On high-pressure distribution systems, either a weight-loaded or pilot-controlled district regulator may be used. Pilot-controlled regulators, although more intricate and expensive than the weight-loaded types, are much more easily adapted to automatic or remote control installations.

Probably the majority of automatic or remote pressure control installations are used for the purpose of maintaining a minimum pressure on a distribution system in order to minimize leakage. The four most general methods of doing this are: (1) By manual control of the main distribution regulator in conjunction with means for continually knowing the pressure existing at the weakest point in the system. (2) By the use of automatic pressure booster equipment which delivers a pressure determined by the flow through the regulator. (3) By means of devices which will vary the pressure according to a pre-determined time schedule. (4) By means of completely automatic equipment which will continually maintain a constant pressure at the weakest point in the system regardless of the demand. The details of each of these methods will be discussed in order.

1. Manual Control

The first of these is the simplest, and consists of manually adjusting the distribution regulator as the load varies throughout the day, so that the pressure at the weakest point in the system is always adequate to provide proper service to the consumer at that point. This cannot be done safely unless the operator at the point is continually informed of the pressure condition existing at the weak point. This could be done by having a man stationed at the remote point, in constant telephonic communication with the operator at the gas distribution plant. In case a sudden increase in load caused the pressure to drop to a dangerously low value at the weak point, the man stationed there would immediately notify the operator at the plant who would then add weights to the regulator or adjust a pilot control and so raise the outlet pressure. The capital investment for such a system would be merely the cost of the pressure gauge at the remote point. However, the operating expenses would be so high that it is doubtful whether such a system could ever be justified.

Practically the same result could be accomplished at a fraction of the operating cost, by replacing the man at the remote point with some form of long distance gauge or indicator, which would inform the operator at the plant of the pressure existing at the remote point. Unless the gauges are damaged through carelessness most instruments involve practically no expense except the original cost of the equipment and the rental of the telephone company's channels over which they operate. Both costs depend upon the distance between the two points involved.

Telephone company charges for signal or control channels entirely within an exchange area vary as between localities. The charges for interexchange channels vary with the airline distance between the rate centers of the exchanges involved. In the case of channels wholly within exchanges and for local channels connected with interexchange channels, the charges are based upon a measurement of airline distance or actual route mileage, depending upon the type of pricing in effect in any particular exchange. It is impossible to cover this point with any general statement; each installation must be considered separately from all angles. It is advisable to secure quotations from the telephone company in each case, rather than attempt to guess or compute charges for control channels.

Our company is at present operating seven remote pressure gauges over telephone channels. The distance between the extremities of the circuit in these cases varies between ¼ and 5 miles, and the flat rental charge varies between $5 and $13 per month.

Since it is customary in the usual telephone practice to run all circuits through the central office of an exchange, in many cases it will require perhaps 10 or 15 miles of telephone circuit to connect two points 5 miles apart. This fact must be taken into account when considering the type of instrument to be installed. Although long distance gauges of the induction balance and self-synchronous motor types are usually the least expensive, the complete installation costing about $250, they will not operate satisfactorily if the resistance of each wire in the circuit is much greater than 100 ohms. This fact limits the use of this type of equipment to between ¾ of a mile and two miles of average telephone cable, or about 25 miles of No. 10 open wire. For distances beyond these, it is necessary to employ more expensive equipment. Since the telephone companies place definite limits on the voltages carried on their circuits, it is not possible to extend the working distance between instruments of this type by raising the line voltage, unless it is economically practical for the gas company to rent pole space or maintain its own private line.

If it is necessary to operate the long distance pressure gauges over 2 miles or more of average telephone circuit, a more sensitive type of instrument must be chosen. Such instruments, employing photoelectric cells, vacuum tubes, and other complex parts, necessarily have a higher initial cost, although the operating expense may be even less than that of a cheaper instrument. Long distance pressure indicating gauges of this class, suitable for operation over 30 miles of ordinary telephone circuit having a resistance of 3,000 ohms per wire, will cost between $500 and $800 for the complete installation. Pressure recording instruments of the same class cost from $100 to $300 more than the indicating types.

The adoption of remote pressure indicating or recording devices can be economically justified only if their use results in better service or lowered operating costs. The less the initial cost of the instrument, therefore, the greater will be the number of cases where it can be used. The complexities of the long distance pressure gauges makes their cost high; especially if they are designed to be operated between two widely separated points. In many cases less expensive substitutes can be used to advantage in applications where the long distance between the source of supply and the remote point makes it impossible to use the cheaper induction balance or self-synchronous motor types.

In most applications of automatic or remote pressure control on gas distribution systems, the object is to so control the pressures at the point where gas is fed into the system, that the pressure at the weakest point on the system is at all times just high enough to render adequate service at that point. Any pressure higher than this results in unnecessary leakage.

Since the pressure to be maintained at the weak point is a constant, any signaling device that will show at the point where gas is fed into the system whether the pressure at the remote point is correct or high or low, can be substituted for an ordinary long distance pressure gauge.

A satisfactory device of this type consists of an arrangement of electric relays which by means of colored signal lights, indicate to the operator in the plant that the gas pressure at the weak point in the system is either above, below, or within, the predetermined operating range. If the pressure at the remote point is to be safely held at a minimum, it is desirable to supplement the signal lights by alarms which will give an audible indication that the remote pressure is not within the safe operating range.

Such an installation can be built for about $150 and will operate satisfactorily through circuits having resistances as high as 2,000 ohms per wire. This value is equivalent to 22 miles or more of average telephone cable. An indicating system of this kind, while not having the flexibility of a long distance pressure gauge, will be applicable to many more cases because of the lower cost.

A short time prior to 1931 a long distance gauge of the induction balance type was installed in our Santa Barbara district to inform the plant operator of the pressure conditions existing at the weak point in the distribution system. However, it was impossible to make the apparatus work satisfactorily because of the length of the line wires running between the outlying point and the gas plant. In this installation it required about 6 miles of telephone circuit to connect the two points, although the airline distance between them was less than 2 miles. It was found that each wire in the circuit had a resistance of 388 ohms, nearly four times the maximum allowable for proper operation of the instrument. It was thought that by renting pole space we could use an open wire circuit of lower resistance, but investigation showed that this was not practical in this instance, because the rental cost would have been so great. For these reasons the idea of using the induction balance type of instrument in this installation, was abandoned and a search

*Submitted by H. J. Keeling, Southern Counties Gas Co.

for a suitable substitute was made. It was found that the most inexpensive instrument on the market capable of operating in this application would cost $400 or more. We decided, therefore, to develop a cheaper and less elaborate device in our own shops. The results were very gratifying; for about $150 we were able to construct a remote pressure indicator, which would operate satisfactorily over two line wires having a resistance as high as 2000 ohms each. Since that time three similar installations have been made and the instruments have been giving satisfactory service for over a year.

Fig. 1.

Fig. 1 is a photograph of the exterior of the original receiver. The signal lamps below the words "low", "correct", and "high", are colored red, green and yellow, respectively, and give a visual indication of the pressure conditions existing at the transmitter. In some installations supplementary bells and other alarms have been added so as to give an additional audible signal when the pressure is not correct.

Fig. 2 is a view of the interior of the receiver, showing the relays and power supply. The apparatus requires 110-volt alternating

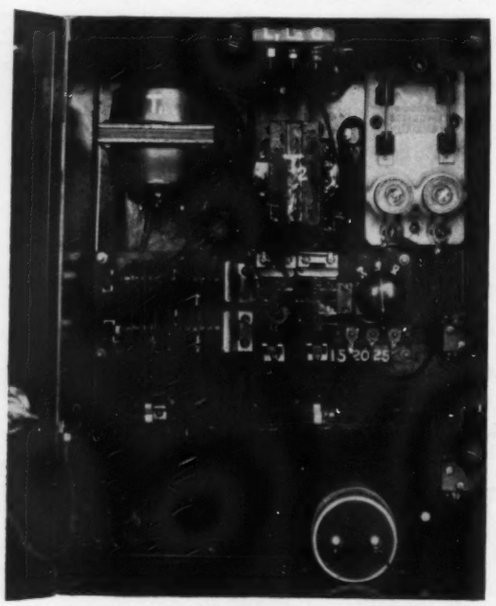


Fig. 2.

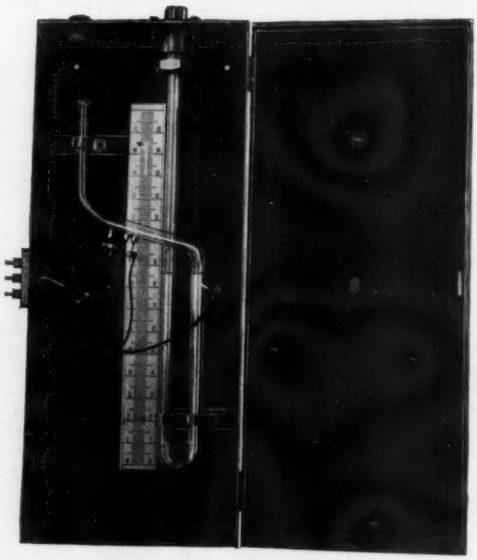


Fig. 3.

current power at the receiving end only, and consumes about 10 watts. The two line relays are on the extreme right hand side of the case. The panel in the center supplies rectified direct current power for their operation. The transformer in the upper left hand corner supplies low voltage power to the three indicating lamps.

Fig. 3 is a photograph of the transmitter with the door open. It consists essentially of a mercury-filled glass tube which is connected with the gas distribution system at the remote point. The two line wires are attached to a pair of contacts sealed into the glass. The mercury column which is electrically connected to ground, comes in contact with these connections when the pressure causes it to rise in the tube. The design is such that the contact is from mercury to mercury rather than from mercury to another metal. This eliminates any difficulty caused by dirt floating on the surface of the mercury. Extra contacts are provided so that the range between the upper and lower limits can be varied. The pressure range is varied by changing the amount of mercury in the tube. With the mercury at rest as shown in Fig. 3, the red lamp at the receiver would be lit. When the gas pressure reached 1½ pounds per square inch, the top of the mercury column would just touch the first contact, extinguishing the red lamp, and turning on the green one. If the pressure increased sufficiently to allow the mercury to touch the upper contact, the green light would be extinguished, and the yellow light turned on. With the adjustment as shown in the photograph this would take place when the pressure is 1¾ pounds per square inch.

This equipment has made it possible to operate four of our distribution systems all the year round with a pressure of only 1½ pounds per square inch at the weakest point. In one case, there are several large consumers located near the extremity of the system. Although they operate intermittently without warning, the variation from the standard pressure at the weak point is always less than ½ pound per square inch. Before installing the indicators it was common practice to find from 4 to 6 pounds per square inch pressure at the same point.

2. Pressure Boosters

The second method of maintaining a minimum pressure on a gas distribution system is by the use of automatic pressure booster equipment which delivers a pressure determined by the flow through the regulator. On low-pressure distribution systems, where the increase in distribution pressures required to care for heavy demands is small, automatic boosters have proven quite satisfactory. However, no entirely satisfactory automatic booster for high-pressure systems has to our knowledge been developed. All such devices are unstable in operation. When the load starts to increase, the booster begins to increase the pressure. This increase in pressure at the regulator immediately causes a great inrush of gas into the distribution system to pack it up to the new pressure. This inrush causes the booster to increase the pressure still farther. This runaway effect on low pressure systems is not as difficult to control because the quality of gas required to raise the system to the new pressure is so small.

A two-pressure booster, that is, one that holds one pressure on a system when the load is light and then boosts to any desired higher

pressure when the load reaches a given amount, is the only type that we have been able to operate successfully. A satisfactory installation of this kind consists of a pressure regulator operating in conjunction with two pilot controls each set at different pressures. The pilot set at the higher pressure is cut in and out of service by means of a diaphragm-operated valve controlled by a differential switch or similar mechanism, which is set into operation by a change in the differential pressure across an orifice. During off-peak hours the pilot set at the lower pressure controls the regulator, the higher pressure pilot being out of service. As the load increases, the differential across the orifice will become greater, until it will finally reach a value where the differential switch will open the diaphragm-operated valve and so put into operation the pilot set at the higher pressure. As the load drops off, the reverse will take place; the differential switch will cut the higher pressure pilot out of service and thus leave the regulator under control of the pilot set to the lower pressure. The total cost, excluding the regulator, of such an installation will vary between $60 and $200, depending upon the circumstances.

Although a booster regulator set-up will not provide as close a degree of minimum pressure control as can be obtained with some of the other methods, it usually has a much wider field of application because of the low operating cost. It can be installed in places where it would not be economical to rent telephone circuits or where electric power service is not available. This type of installation can also be used as either a supplementary feed for a system, or as a standby regulator which would operate automatically in case the main source of supply failed. For this application the booster pilot is operated by a change in pressure rather than a change in differential.

Fig. 4 is a photograph of our Santa Monica distribution regulators having automatic equipment for boosting the distribution pressure when the load reaches a certain value. Fig. 5 is a piping diagram of the same installation.

Referring to the above illustration, pilots No. 1 and No. 2 feed gas from the holder line to the head of the regulator. Pilot No. 2, set at 4 lbs. per sq. in., is cut in and out of service by the electric valve A, which is controlled by a time clock. This clock cuts in pilot No. 2 at certain hours of the day when the minimum pressure necessary is 4 lbs. per sq. in. During the night and off-peak periods, pilot No. 2 is cut out of service, so that pilot No. 1 maintains the distribution system at 3 lbs., providing of course, that the booster device is not operating.

The booster pilot No. 3, set at 5 lbs. per sq. in., contains an auxiliary diaphragm above the lower diaphragm, so that the upper side of this diaphragm can be left open to atmosphere. Consequently the pilot can be shut off completely by the application of pressure to the under side of the lowest diaphragm.

The operation of the booster is as follows: The differential switch is connected across an orifice located on the downstream side of the regulator. When the differential across this orifice exceeds a certain pre-determined value, the differential switch operates, shutting off the supply of pressure to the control line of the booster pilot. The pressure trapped under the lower diaphragm of the pilot then bleeds out to atmosphere through mechanism in the differential switch. The removal of this pressure allows the booster pilot to open and feed gas to the head of the regulator, raising the distribution pressure to 5 lbs. per sq. in. When the distribution load drops off, and the differential returns to normal, the differential switch applies pressure to the control line of the booster pilot, cutting it out of service. The regulator pressure then drops down to either 3 lbs. or 4 lbs. per sq. in., depending on whether the electric valve A is open or closed.

Fig. 6 is a diagram of a standby regulator installation which provides for the automatic feeding of a distribution system from a secondary source of supply in case of interruption to the main feed. The shut-off pilot No. 1 is set to open when the distribution pressure drops to the minimum safe value. Normally therefore, it remains closed. Since there is no other pilot feeding the head of the standby regulator, the pressure above the diaphragm equalizes through the bleed to atmosphere. Thus, with atmospheric pressure on the top of the regulator diaphragm and the distribution pressure on the under side, the regulator valves are kept closed with considerable force. This prevents leakage through the standby regulator during normal operations.

The control pilot No. 2, is set to maintain the pressure required to carry the distribution load. This pilot is a single diaphragm pilot, and operates like any other spring-loaded regulator.

The shut-off pilot has an auxiliary diaphragm above the upper diaphragm. This extra diaphragm is larger than the other two. The space between the two upper diaphragms is open to the atmosphere and the connection to the chamber above the uppermost diaphragm is tied into the outlet of the control pilot No. 2 in Fig. 6. Consequently, as soon as the shut-off pilot opens, it puts pressure on the upper auxiliary diaphragm, which on account of its larger area, causes the valve to remain wide open until it is shut off by hand.

The operation of the stand-by regulator is as follows: In case of interruption in the main supply, the pressure in the distribution

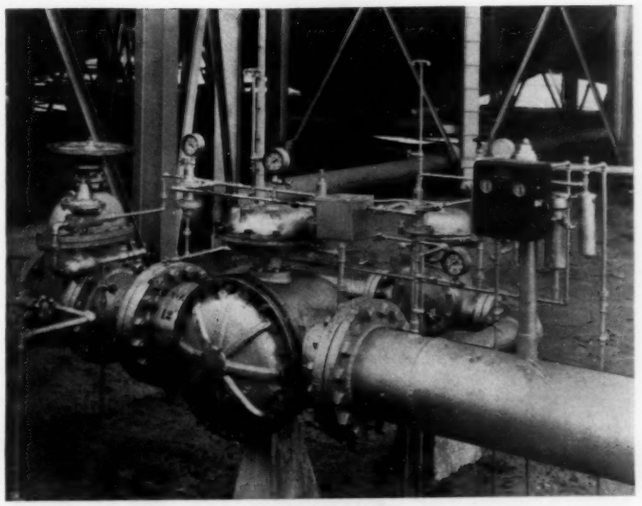


Fig. 4.

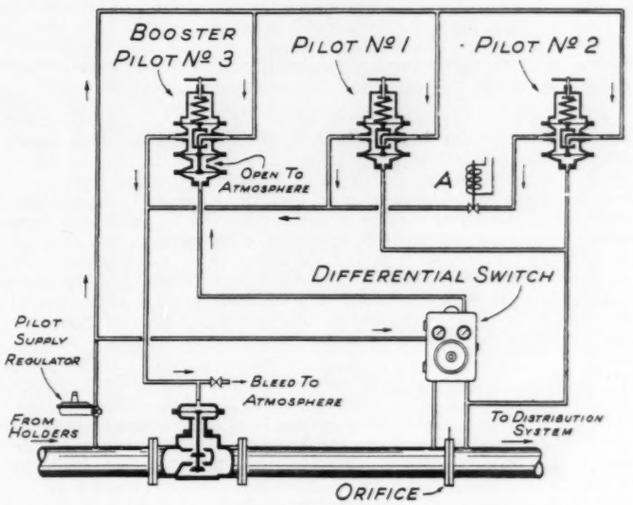


Fig. 5.

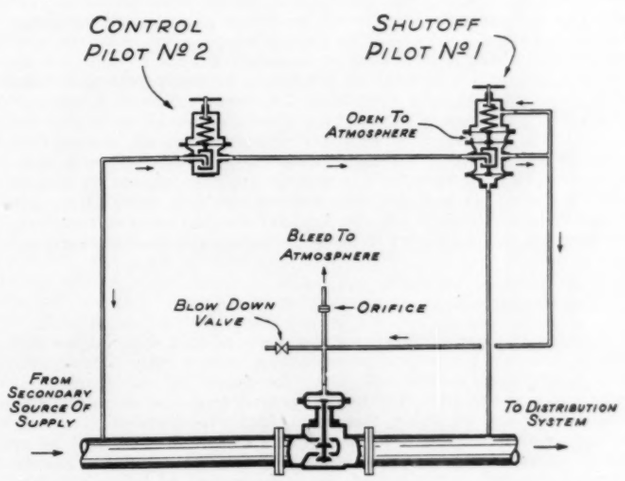


Fig. 6.

system will drop, allowing the shut-off pilot to open. The control pilot will then feed gas through the valve of the shut-off pilot to the head of the regulator, allowing it to supply the distribution system from the secondary source. Also, due to the construction of the shut-off pilot the regulator will continue to feed the distribution

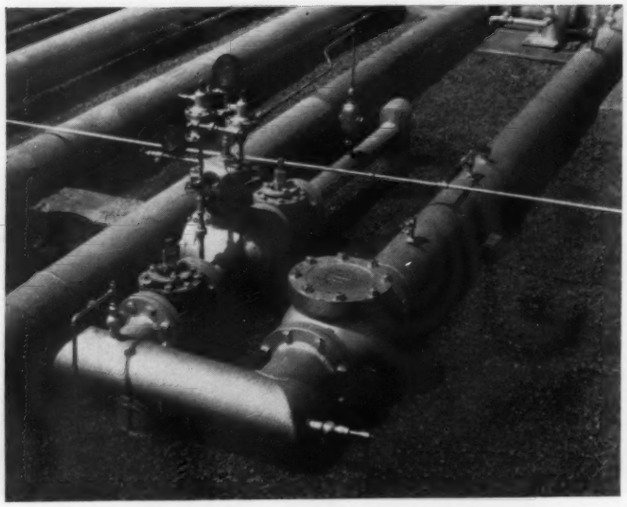


Fig. 7.

system until the blow-down valve on the head of the regulator is opened by hand.

Fig. 7 is a photograph of a stand-by regulator installed near the source of supply for our Whittier distribution system. This set-up supplies the feeder line from a secondary source in case of interruption to the main supply. A check valve prevents gas from flowing from the stand-by regulator back into the main line. The operator is notified of the low pressure condition by an electric horn which is set into operation by means of a pressure switch attached to this line. The main line and the check valve are shown on the extreme right of the picture. The stand-by regulator and the main supply line are both connected to a common header which is tied into the feeder line to the distribution system. This line rises vertically out of the ground near the bottom of the picture.

3. *Time-Pressure Devices*

If the load on a distribution system is of such a nature that the pressure required at any hour can be predicted with certainty from day to day, it is possible to maintain a minimum pressure by using a clock controlled instrument to govern the outlet pressure of the distribution regulator. The apparatus costs about $135 and consists essentially of a clock-driven cam which controls the pilot pressure. By shaping the cam in the proper manner the device will cause the regulator pressure to follow any desired program during a 24-hour period. This mechanism is very useful in any application where it is desired to maintain a pressure-time schedule, and it can also be used to advantage in making the operation of high-pressure holders completely automatic. The disadvantage of distribution pressure control by a time schedule alone is obvious. In case the load deviates very far from normal, the distribution pressure will be either too high or too low. If this system is supplemented by a differentially operated pressure booster as previously described, it is possible to operate safely in spite of an abnormally large demand. If the load is less than normal, however, the pressure will be higher than the minimum required at that particular period.

4. *Remote Control*

In order to automatically vary the pressure on a distribution system to maintain a constant pressure at a remote point, it is necessary to employ a mechanical means for governing the distribution regulator pressure according to the pressure at the weak point. The simplest method of doing this is to feed the distribution system by means of a loop, so that the extreme end of the line will be at the plant, adjacent to the feeding point. The regulator control line is connected to the end of this loop, instead of being tied into the outlet side, as is customary. By this means the regulator will automatically maintain a constant pressure at the end of the loop, which is the weakest point in the system.

Although this method of automatic control is the least complex as far as the operation is concerned, it is not readily adaptable to existing distribution systems. Also, the use of a distribution feeder in the form of a loop is an uneconomical design. These objections make the application of this method economically practical in only a very few cases; however, it is mentioned here because from the theoretical standpoint, it is probably the most perfect system of automatically maintaining a minimum pressure on a distribution system.

The second, and probably the most practical method of automatically maintaining a constant pressure at a remote point is by employing electrical equipment operating in conjunction with telephone circuits. The most flexible control is obtained by using a remote pressure gauge to control the regulator at the supply point. With this scheme it is very easy to adjust the setting of the instrument at the source of supply so that any desired constant pressure will be maintained at the remote point. The operation of this apparatus is as follows: Electrical contacts located on either side of the hand on the receiving instrument close relay circuits whenever the gauge indicates that the pressure at the remote end is other than normal. These relays in turn, set into operation a motor-driven pilot regulator or other equipment which adjusts the outlet pressure of the main regulator so that the pressure condition at the remote point is corrected. As long as the hand on the pressure gauge floats between the upper and lower limit contacts, the motor-driven pilot will remain at rest. If a change in the load modifies the pressure at the remote point beyond a certain limit, the hand on the receiving instrument will immediately respond and make contact with the adjacent points, and so adjust the regulator to take care of the new conditions.

The initial cost of an installation of this kind will be somewhat higher than merely the cost of the remote pressure gauges and the motor-driven pilot. This is due to the fact that to ensure the safe operation of any automatic installation, it is necessary to install various protective devices which will prevent the arising of a dangerous pressure condition in case the apparatus should become defective or inoperative. These safety devices will be discussed more fully in another part of this paper.

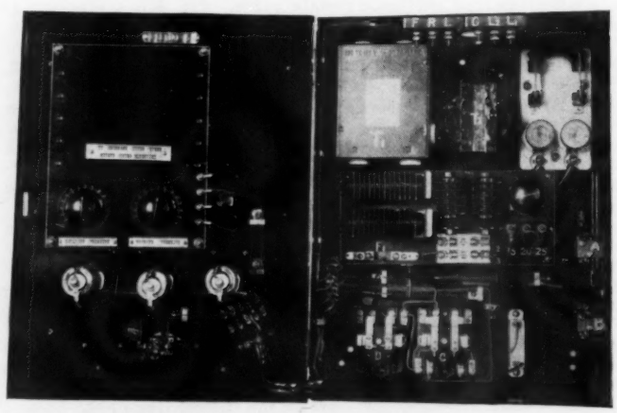


Fig. 8.

The total cost of the complete installation with all accessories, will be from $100 to $200 more than the cost of the long distance gauges used. As previously shown, the initial cost of the remote pressure gauges will depend upon the distance between the two points involved. The inexpensive remote pressure indicator employing relays and colored lights is readily adaptable to the work of automatically maintaining a constant distribution pressure. The relays in this mechanism, in addition to lighting signal lamps, can be used to control a motor-driven pilot which will automatically adjust the regulator whenever the remote pressure is either above or below the normal value. With this apparatus, since the high and low contacts are on the transmitter located at the remote point, any manual adjustment of the upper and lower pressure limits must be made there rather than at the receiver. This advantage is very slight, however, because as stated before, there is very little need of ever changing the minimum pressure maintained at the weak point in the distribution system.

Fig. 8 shows the interior of our remote pressure indicator receiver equipped for automatic control.

The two large relays in the lower part of the case are used to control the motor-driven pilot. The pilot is of the double-diaphragm type, and is driven through suitable gearing by a single-phase alternating current induction motor. The motor and gears are completely enclosed in an oil-filled casing. The design of the motor is such that it will not be harmed by overloading or stalling.

The speed of the motor pilot is controlled by the knobs on the panel attached to the inside of the door, shown on the left. The apparatus is adjusted so that the motor operates faster when raising

the pressure than it does when lowering the pressure. This is done to correct a low-pressure condition quickly without causing hunting or over-correction due to pack in the system.

Additional relays, not shown in the illustrations, have been provided in order to protect the apparatus against power failure, open or short circuits in the telephone circuit, transformer burnout, or other failure in the instrument itself. In case any of these failures occur, or in the event that the red light (indicating low pressure) remains lighted for longer than three minutes, a solenoid operated valve will drop open, putting into operation an emergency pilot regulator. This pilot is set to a value high enough to provide the distribution system with adequate pressure under all circumstances. A standby regulator is provided as a safeguard in case the main distribution regulator should become inoperative. The head of this regulator is tied in to the head of the main regulator, but the valves are weighted so that they will open at about ½ pound per square inch less pressure than the main regulator. By this means the standby regulator is kept shut off, as long as the main distribution regulator is in operation.

In addition to these safeguards, another standby regulator fed from a secondary source of supply is installed near the outskirts of the system. This regulator will be automatically put into operation in case the distribution pressure at that point ever becomes dangerously low.

It is usually uneconomical for an operating company to develop and manufacture equipment such as remote control devices. However, at present it is not possible to secure equipment designed to meet the special needs of gas distribution work. Under these conditions a gas company is forced to develop its own remote pressure indicators. The manufacturers of this type of mechanism should not ignore the great possibilities for the extensive use of relatively simple and inexpensive indicators which are not now obtainable in the market.

TRANSMISSION COMMITTEE

B. M. Laulhere, Southern California Gas Company, Chairman

Transmission Pipe Lines*

INTERNAL CORROSION OF NATURAL GAS TRANSMISSION LINES†

DURING the past few years several investigators have reported their experiences with the internal corrosion of gas transmission lines on the Pacific Coast. ** While in each case their problem was of a local nature, considerable information was made available as to the general character and probable causes of this destructive action. In 1932 a good number of cases of internal corrosion of natural gas pipe lines were brought to light and it soon became recognized that the problem was one of a general nature, deserving of joint study.

The committee formed for this work has attempted to gather all available information pertaining to the existence and cause of the corrosion of natural gas transmission lines as well as to suggest actual methods and steps for eliminating it. The existence of the corrosion and its various effects are known facts, while the corrective methods are offered as a definite basis for future work. The report is divided into five parts, which are as follows:

1. Causes of internal corrosion.
2. Effects of internal corrosion.
3. Methods of detection.
4. Field experiences.
5. Methods of mitigation.

R. L. Cook
Chairman

1. CAUSES OF INTERNAL CORROSION

The internal corrosion of transmission lines in California has been shown to occur in the presence of liquid water, and either oxygen or hydrogen sulphide, or both. In no case has corrosion been reported in the absence of liquid water. The presence of any one of these agents in a pipe line, however, does not necessarily mean corrosion is taking place.

The occurrence of the corrosion appears to be dependent upon so many factors—among them being pressure, concentrations of reacting substances, drainage, contour of the line, and others, not thoroughly understood at this time—that it is exceedingly difficult to predict when and where it will occur. Corrosion is found in one section of a pipe line and not in others, and therefore numerous inspections must be made before it can definitely be said that corrosion does not exist.

The liquid present in pipe lines results from condensation. Natural gas as it comes from the absorption plant is usually warm and saturated with water vapor. Upon entering the pipe lines its temperature drops, and as a result, liquid water condenses. It is at these points that internal corrosion is generally encountered.

Hydrogen sulphide is sometimes a constituent of natural gas as it comes from the well, and its presence is therefore independent of plant or pipe line operation. In some fields it does not occur at all, but does in others, sometimes running as high as 2.0 grains per 100 cubic foot of gas. Very small amounts, undetectable with ordinary analytical apparatus, have been shown to exist and to be an important accelerator of internal corrosion. These instances will be discussed later in detail.

Oxygen is thought to be a constituent of well gas in some localities but is usually present in natural gas pipe lines as a result of contamination by air. The chief sources of air have been found to be in tank vapors and from leaks in vacuum-collected gathering systems. Some years ago when the California fields were first brought in, well pressures were high; but continual production over long time periods has made it necessary to resort to vacuum-collection of the gas. A significant fact is that this condition cannot be expected to improve in the future and, therefore, corrosion troubles should gradually become more severe unless corrective measures are taken.

The chemical reactions involved in the corrosion appear to be many, and again, are dependent upon the local conditions existing in the pipe line. In all cases, it is felt that the first step in the action depends upon the dissolving of oxygen or hydrogen sulphide in the condensed water on the pipe walls. The attack on the iron then follows through this medium. A recent investigator has suggested that carbon-dioxide, dissolved in condensed water vapor, can also act in a corrosive manner. This constituent of natural gas has long been considered to be a non-corrosive. If dissolved oxygen reacts with the pipe, red iron oxide is formed, while hydrogen sulphide under the same conditions reacts to give black iron sulphide. In most cases investigated during the past year, the pipe line deposits have been shown to consist of a very high percentage of red iron oxide.

Other compounds formed depend upon the reaction of the corrosive constituents with themselves, such as the deposition by hydrogen sulphide of free sulphur, also the formation of sulphuric acid by the oxidation of hydrogen sulphide.

It should be emphasized at this point, that the reactions described above only take place, to any degree, when natural gas is at high pressures. At pressures below 75 pounds, doubtless, some action occurs; but in no case of severe corrosion reported, has the pressure been below this figure.

Internal corrosion in low pressure mains serving manufactured gas has been investigated in the past and found to be a common occurrence; however, the sulphide content is usually higher than in natural gas, the gas contains other corrosive constituents, and is saturated with water vapor at the lower pressures.

The explanation for the severe corrosion at high pressures has been that, besides the saturated gas condition, the partial pressure of the oxygen and hydrogen sulphide is increased many fold over what it is at atmospheric pressure. This greatly increases their solubility in the condensed water vapor at high pressures.

Mechanical erosion of pipe interiors by sand, condensed water, and scale, is a factor in pipe deterioration, but is distinguished from corrosion. These points have been well recognized in the past and will not be discussed in this report.

*Committee Report: R. L. Cook, chairman, So. Calif. Gas Co.; A. B. Allyne, So. Counties Gas Co.; P. E. Beckman, P. G. and E. Co.; M. T. Burton, So. Calif. Gas Co.; H. S. Harris, L. A. G. and E. Corp.; Earl Jinnett, So. Counties Gas Co.; C. E. Pickup, So. Calif. Gas Co.; Wm. Pipkin, So. Fuel Co.; Carl Summers, So. Counties Gas Co.; F. E Wilson, P. G. and E. Co.

†Sub-Committee Report: A. B. Allyne, chairman, Southern Counties Gas Co.

**See Bibliography.

2. EFFECTS OF INTERNAL CORROSION

The effects of internal corrosion are easily recognized and need little or no discussion. A portion of them are listed below.

(*a.*) *Rusting and Pitting of Pipe.* Continued action on the interior pipe walls results in a diminished wall thickness and ultimate failure. No definite statement can be made as to whether general rusting or localized pitting will occur. Under certain conditions, the corrosion products have been shown to slough off the pipe walls, leaving a fresh steel surface exposed, while in other cases the compounds formed have furnished a hard protective scale for the pipe. Several cases are known where the pipe was deeply pitted to one-half penetration within but a few year's time.

(*b.*) *Reduced Capacity of Line.* The capacity of a line experiencing internal corrosion is possibly reduced in three ways. The actual inside diameter of the pipe is decreased, due to the building up of layers of corrosion products. Condensed water likewise reduces the pipe volume unless proper drips are installed. Finally the friction is increased, due to the gas passing over the roughened pipe wall or corrosion layer. Excessive pressure drops in given distances along a line are a good indication of the action going on within the pipe.

(*c.*) *Clogging of Meter Runs, Valves, etc.* Orifice meter set-ups usually bear a good share of the troubles resulting from internal corrosion. Either they are actually chemically attacked themselves, or they become clogged with the large volumes of corrosion products from the corrosive actions upstream. In addition to the frequent destruction of the orifice plate itself, large losses are incurred from inaccurate metering. Valves and fittings often become so clogged with scale and rust products, that their proper operation is impossible.

(*d.*) *Distribution Systems*: Although nearly all the actual pipe corrosion is thought to occur within a few miles of the compressor plants, the huge volumes of corrosion products are often carried along many miles by the gas velocity and finally emerge into the distribution system, creating serious dust problems.

3. METHODS OF DETECTION

At the present writing, several methods have been proposed for the detection of the corrosive constituents in natural gas and the corrosion resulting from their action. They are:

1. Actual inspections and study of operating data.
2. Insertion of test set-ups on operating lines.
3. Chemical methods of detecting corrosive constituents.
4. Electrical methods of detecting oxygen.

Doubtless, the most convincing method of detecting internal corrosion is to actually make inspections of sections cut from the line in question. This, however, is a relatively expensive procedure in most cases, and may reveal the damage only after considerable corrosion has already taken place. Actual inspections are recommended after other detection steps have indicated corrosion to be occurring and before any large monetary outlay is made for corrective measures.

Investigation of pipe line operating data may reveal to some extent the presence of internal corrosion. As mentioned before, pressure drops in a given length of line, greatly in excess of those indicated by gas flow formulae, should be investigated. Collection of large amounts of water in drips, dust troubles, and the condition of orifice plates, are also useful in such a study.

In attempts to obtain information regarding internal corrosion, several companies operating pipe lines have devised set-ups for inserting metallic test strips into the gas stream for periodic inspection. These set-ups may be installed on operating lines without a shutdown and enable a continuous check at any number of points along a line. Fig. 1 shows such a set-up on an operating line of the Southern Counties Gas Co.

Bridge crossings, and existing vaults are convenient locations for these set-ups, thereby eliminating the need for special vaults. They consist of a 2-inch valve, nipples, and cap, fitted with a packing gland and brass rod as shown. The metal sample is attached to the end of the brass rod by two small machine screws. Valve and nipples are installed under operating conditions by use of a tapping machine. The rod, with sample attached, is inserted in the packing gland and the 2-inch cap screwed into place. Next, the valve is opened and the rod pushed down until the sample is in the middle of the gas stream. Tightening of the packing gland completes the installation. If the corrosive action of any liquid travelling along the bottom of the pipe is desired, the sample is slightly bent one inch from the bottom before insertion and then pushed against the bottom of the pipe upon installation. This places the bottom inch of sample in the liquid and the remainder in the gas stream. The samples used are either steel or copper, and are 1 inch x 8 inches in size. The Southern Counties Gas Co. has installed about 30 such set-ups, which are each inspected at least every three months. The visual condition of the sample is recorded, and in case severe corrosion is revealed, the loss of weight determined. It is believed that these samples not only indicate the corrosive action taking place, but also picture the moisture and dust condition in the line. If present, they are deposited on the surface of the samples.

The apparently minute concentrations of oxygen and hydrogen sulphide needed for the experiencing of internal corrosion has made it exceedingly difficult to measure their amounts in a quanitative manner. The ordinary Orsat and the Burrell gas analysis apparatus for oxygen determinations will not detect small amounts; while the Tutweiler method for hydrogen sulphide detection is valueless for the same reason.

Recently, due to research by several gas companies, chemical methods have been developed for determining very small quantities of these substances. The method for oxygen determination will be found described in the report of the Chemical Laboratory Methods Sub-Committee, while the refined procedure for hydrogen sulphide determination is discussed in another part of this report.

Methods for determining the humidity of natural gas are well known. The most common of these are the wet and dry bulb method and actual absorption of the water from a definite volume of the gas by a suitable absorbent, usually phosphorous pentoxide.

Investigation is being conducted at the present time as to the possibility of adapting the electrical filament principle, used for detecting combustible vapors, to indicate small quantities of oxygen in a gas mixture instead of small amounts of hydro-carbons in an air atmosphere. Preliminary work has indicated that about 0.02 per cent oxygen might be measured in the field. It is hoped subsequent work will considerably reduce this figure. Continuous oxygen recorders, as well as alarm systems to warn of excessive air contamination in pipe lines, are being studied. The need for such testing equipment has long been felt.

4. FIELD EXPERIENCES

Illustrative of the internal corrosion problems being encountered at the present time, there are reported below the experiences of several companies in various California gas fields.

The Ventura field gas, until recently, has been considered non-corrosive. Ordinary testing apparatus showed no oxygen or hydrogen sulphide, although it was known that large volumes of water were condensing in the transmission lines. A badly pitted pipe interior removed in 1931 gave the first indication of a corrosive con-

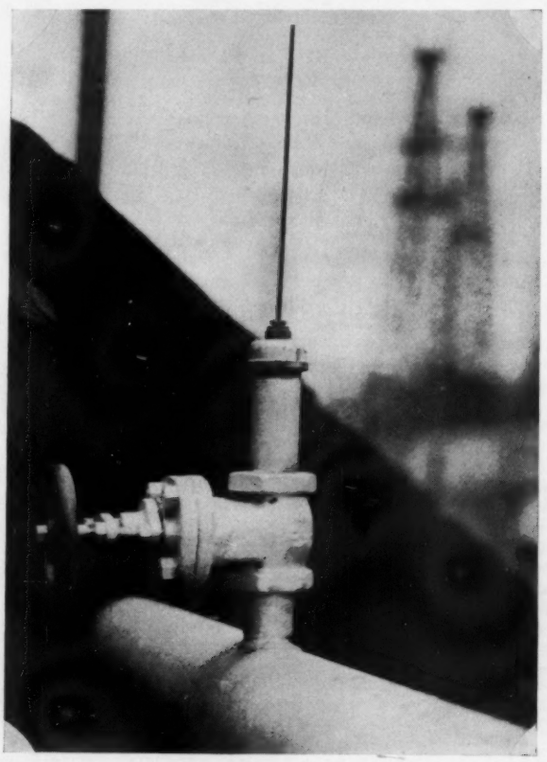


Fig. 1.

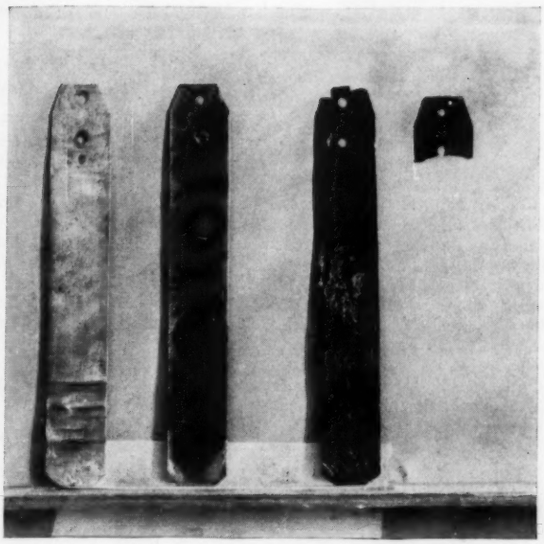


Fig. 2.

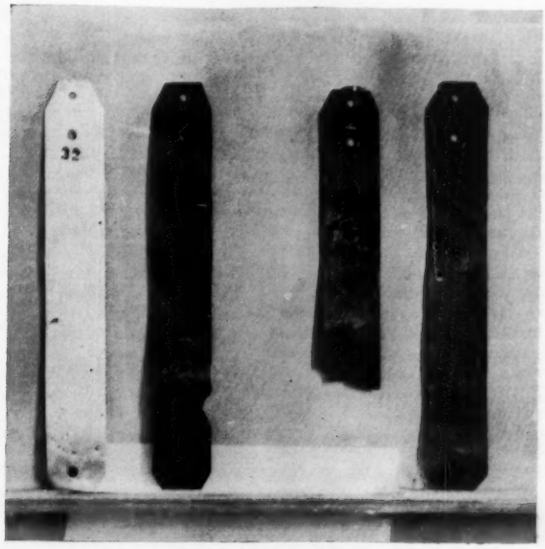


Fig. 3.

dition and led to the installation of several corrosion test set-ups (see Fig. 1) in 1932. In a very short time the samples, both steel and copper, were badly corroded, indicating the probable existence of corrosive constituents in the gas mixture. Examples of these samples are shown in Figs. 2 and 3. Fig. 2 shows four steel samples. The one on the extreme left was installed in the intake of a compressor plant, the pressure being 25 pounds. It was still bright when removed after four months. The other three steel samples were removed from various locations on the plant discharge line, operating at between 375 and 400 pounds pressure. These three samples, before cleaning, were covered with a thick, black, wet muck that turned red when exposed to the air. They were exposed to the gas flow for from three to six months.

The samples shown in Fig. 3 are all copper. The one shown at the left is a new sample, never installed. The next one shows the effects of 18 days action in the same line as described above. The sample is seen to be covered with a heavy, loose black scale, and is penetrated near the bottom.

The two samples shown on the right in Fig. 3 demonstrate the effect of pressure on corrosion. These copper samples were placed in a line fed by the Ventura field. The sample on the left was installed ahead of the district regulator and was subjected to about 90 pounds pressure. The one on the right was downstream from the regulator, yet but 6 feet from the other sample. The pressure in this case was 2 pounds.

Tests for hydrogen sulphide in the Ventura field by the White method have shown roughly 0.0077 grains per 100 cubic feet to exist in the well gas. Accurate oxygen tests have not been made but the oxygen content is believed to be less than 0.1 per cent, on the average. Sudden breaks, of course, in vacuum systems will greatly increase this figure.

The Venice field, which was brought in during the latter part of 1929, was expected to be rather corrosive, as tests made in 1930 showed relatively large amounts of hydrogen sulphide present, running in some cases to 2.0 grains per 100 cubic feet. Contrary to expectations, no serious corrosion was reported until May, 1933. Possibly one reason for this was that the lines leading from the field were nearly all operated at relatively low pressures, around 30 pounds. Due to the collection of much of the gas under vacuum and the pumping of considerable quantities of tank vapors, the oxygen content usually runs, on a composite sample, about 1.0 per cent.

An orifice plate removed from a meter at a Venice compressor plant discharge in May, 1933, was badly corroded after about three months service. This plate is shown in Fig. 4. The line was at approximately 110 pounds pressure, the gas temperature varied from 68° to 81°, and about 2 million feet of gas were metered per 24 hours. The orifice originally 3.00 inches in diameter was between 3.25 and 3.40 when removed. The black line shows the original diameter. Originally ⅛-inch thick, the plate was razor thin when taken out.

During a temporary shutdown, the interior of the above meter was inspected for corrosion. The run was about half filled with water. When tested with litmus paper, this liquid gave an acid reaction. Large quantities of black scale hung to the walls of the pipe. Upon removing this scale, the pipe was found to be badly pitted, especially so in the lower half. At one point, there appeared to be a smooth channel about 3 inches wide and 1/32 to 1/16

Fig. 4.

inch deep, running along the bottom of the pipe. Near the orifice fitting the pipe was badly pitted, several pits being as much as 0.075 inches deep. After this condition was encountered, other plates in the field were examined. Several of them were found to be pitted, but to a lesser degree.

The occurrence of internal corrosion in the transmission pipe lines from the Inglewood field was described by Burton in 1928, while its presence in the Huntington Beach field was reported by Allyne in 1932.

Internal corrosion in the Kettleman Hills oil field was not made known until 1932. Its occurrence in this field is described in the following report.

*Internal Corrosion in Kettleman Hills Oil Field**

The purpose of this brief paper is to present a description of an internal corrosion condition occurring in natural gas transmission lines in the Kettleman Hills oil field.

In the case under discussion internal corrosion was actually present, but attention to the condition was called, not by failure or penetration of pipe walls, but rather by an excessive drop in pressure.

This pressure drop was first experienced by the Pacific Gas and Electric Co. in its San Francisco transmission line. The company

*Submitted by M. T. Burton, Southern California Gas Co.

found, upon examination, heavy deposits of a finely divided black substance, together with large quantities of water.

Samples of these deposits, together with somewhat similar deposits from the Southern Fuel Co. line, were analyzed. Analyses are given in Table No. 1.

TABLE NO. 1

Constituent	P. G. and E. Line	Southern Fuel Line
Sample	Solid	Solid, 13.45% Liquid 86.55%
Acidity as H_2SO_4	.59%	..... Neutral
Loss on Ignition	12.44	14.22%
Silica	.14	5.76
Ferrous Oxide	4.36	1.88
Ferric Oxide	69.44	76.45
Sulphur Trioxide	15.28	2.67
Lime	None	.48
Magnesia	.14	.44
Soda	None	.10
Potash	None	.10
Sulphides	Trace	None
Sulphites	Trace	None

Both the analyses show the presence of combined sulphur and oxygen. The high acidity of the first sample is of particular interest.

The presence of sulphur and oxygen was, of course, an unexpected occurrence in the Kettleman field, and had never, to the writer's knowledge, been reported.

As previous experience had proved that sulphur and oxygen in the presence of water and pressure, were very corrosive, immediate concern was felt for the safety of all lines in the field.

An investigation was undertaken to determine the nature and extent of any corrosion damage, and also, to determine the concentration of both sulphur compounds and oxygen.

It was evident that the concentrations of both sulphur and oxygen would be very small, or their presence would probably have been reported in the regular course of analyses. Oxygen, particularly if occuring in concentrations of .10 per cent or over, would have been reported.

The determination of small quantities of either sulphur or oxygen is exceedingly difficult.

For the determination of sulphur, which we had reason to believe was present only as H_2S, use of a method developed by the San Diego Consolidated Gas and Electric Co., was decided upon.

This method is calorimetric and depends upon the formation of a distinctive yellow precipitate or cadmium sulphide, the intensity of the color being a measure of H_2S concentration.

Sensitized papers are prepared by treating filter papers with a solution of neutral cadmium acetate. These are exposed in a suitable chamber, so that the gas flows through the paper.

Color standards are prepared from these papers, using known concentrations of H_2S. By comparison of the test paper with the standards and measurement of the gas volume, the concentration per 100 cubic feet is determined.

For use with Kettleman Hill's gas, considerable difficulty was experienced with this method. Some of the objections were as follows:

1. Very large gas volumes must be used, as the H_2S concentration is very small.

2. To insure complete removel of H_2S the gas must pass very slowly.

3. Widely variant moisture conditions seem to give somewhat erratic results. For instance, the color intensity is not always constant for the same concentration. This may probably be attributed to the formation of Cd S at one time only on or near the paper surface, while in a subsequent test a precipitate may be formed throughout the thickness of the paper.

To escape this last difficulty, the method was modified. Instead of employing a visual comparison, the test paper was treated with $\frac{N}{100}$ I_2 in the presence of H Cl with the following reactions:

$$Cd\ S + 2H\ Cl = H_2S + Cd\ Cl_2$$
$$H_2S + I_2 = 2H\ I + S$$

The excess I_2 was then titrated with $\frac{N}{100}$ $Na_2\ S_2\ O_3$ and the quantity of H_2S calculated.

(The method employed for making oxygen tests is described in the Chemical Laboratory Methods Sub-Committee Report.)

Determinations of both hydrogen sulphide and oxygen were made throughout the field. The results are shown in Table No. 2. In most cases check tests were made at later periods.

TABLE NO. 2. TABULATION OF RESULTS OF TESTS AT KETTLEMAN HILLS AND BELRIDGE

Location	*Grains Hydrogen Sulphide per 100 cu. ft.*	*Per cent Oxygen*
Oil Co. A, H. P. Intake	0.048	Trace
Check	0.057	0.00
Oil Co. A, H. P. Discharge	0.008	0.0026
Check	0.025	Trace
*Oil Co. A, Recompressed Gas	0.027	0.007
Check	0.045	0.0168
*Oil Co. A, Tank Vapor	..... (Orsat)	2.40
Gasoline Co. B, H. P. Intake	0.022	Trace
Check	0.031	Trace
†Gasoline Co. B, Plant Vapor	0.065	0.0042
Check	0.079	0.0037
Gasoline Co. B, Tank Vapor	0.000	.....
Check	0.021	0.600
Gasoline Co. B, H. P. Discharge	0.022	0.0037
Check	0.034	Trace
Check	0.034	.....
Gasoline Co. B, H. P. Discharge	0.008	Trace
Check	0.013	0.0053
Gasoline Co. C, H. P. Discharge	0.018	Trace
Check	0.087	0.0045
Southern Fuel Main Line, Valve No. 1	0.004	Trace
Check	0.004	Trace
So. Cal. Gas Co. Lease, Avenal	0.000	.....
Oil Co. D, H. P. Intake	0.038	0.000
Oil Co. D, H. P. Discharge	0.042	0.000
Southern Fuel Co., Main Line, Buena Vista	0.000	0.000

*The re-compressed gas was not tested the same day as the tank vapor. The operation of the tank vapor gas is erratic.

†By plant vapor is meant vapor recovered by steam stripping of absorption oil.

Note: "Check tests were not necessarily taken immediately after the original test. In most cases they were taken several days later.

Hydrogen sulphide is shown to be present in all parts of the field. While oxygen is reported as a trace in some of the intakes of the gasoline plants, it is probable that this is due to some small inherent error in the analytical method, and that oxygen is introduced only through atmospheric contamination in tank vapors.

The quantities of both H_2S and O_2 are small, but as previously stated, experience has shown that even small concentrations of H_2S under certain conditions can produce severe corrosion.

It was shown that in the Inglewood field the controlling factor was not the concentration of H_2S, but rather the depolarization of iron due to the increased partial pressure of O_2 with increasing line pressure and consequent greater solubility of O_2.

In the present case, however, the O_2 concentrations are tremendously smaller, so that instead of the deep pitting encountered at Inglewood, we should expect to find the corrosion general and evenly distributed.

Examination of the lines justified this supposition. With the absence of severe pitting the danger due to corrosion would seem negligible, but a rough estimate of the magnitude of the damage is of interest.

Assuming the maximum concentration of H_2S found (.087 grains per 100 cu. ft.) and 50 M Mc.f. load per day, there will be brought into the line approximately 6 pounds of H_2S per day. This will react with iron to form corrosion products, combining with an equivalent of 10 pounds of iron, which in the form of iron oxide would weigh 14 pounds. This 10 pounds of iron would be removed in the immediate vicinity of Kettleman Hills because H_2S was not found beyond the 6-mile point on the transmission lines.

It is felt that practically all of the contaminating oxygen can be eliminated by discontinuing the practice of taking tank vapors into the transmission lines.

The writer wishes to acknowledge the help of Guy Corfield, in collaboration with whom the work was done.

Mid-Western Experience

Correspondence with at least two mid-western gas companies, has revealed that practically the same corrosion conditions exist there as are prevalent on the Pacific Coast. The general belief is, that the corrosion is caused by the action of both hydrogen sulphide and oxygen in the presence of liquid water. These companies are also greatly concerned with another problem, that is, the actual freezing up of the condensed water vapor in the lines. In addition they have reported, where liquid water is known to exist, the occurrence, above normal freezing temperatures, of an ice formation. This "ice" is believed to be a hydrocarbon hydrate formed at low temperatures and high pressures. The study of this stoppage problem is being continued. It is believed the elimination of condensed water will forestall its formation. Such an "ice" for-

mation was encountered in the Southern Counties Gas Co.'s transmission lines from the Elwood field during the winter of 1931.

D. A. Sillers of the Lone Star Gas Co., Dallas, Texas, in private correspondence, describes scale formation and pitting along the bottom of pipe within the first few miles of the outlet of one of the company's smaller compressor plants. The presence of small amounts of sulphuric acid is also reported. This internal corrosion gave rise to serious dust troubles. Several years ago this trouble was remedied by the installation of Acme gas cleaners near their gasoline plants and compressor stations.

The need for preventing the deposition of condensed water vapor was anticipated ahead of construction in the Natural Gas Co. of America's line to Chicago by the erection of a dehumidification plant at Fritch, Texas. The Chicago line is noted for its dryness. This refrigeration plant is referred to in a later section.

5. METHODS OF MITIGATION

There is little doubt but that total removal of both oxygen and hydrogen sulphide would practically stop internal corrosion; and, although there are several commercial methods for treating gaseous mixtures containing these constituents, none of them will remove the minute quantities that can apparently bring about this corrosion in a high pressure pipe line. The only course, then, that is left open is to dehumidify the gas to such a degree that it cannot deposit condensed water vapor at any point in the line.

Dehumidification processes fall into two general classes. The dew point may be lowered by treatment with a hygroscopic substance or an absorbent, or, the water content can be reduced by cooling of the gas. This cooling may be accomplished in a variety of ways.

In this section of the committee's report are presented a number of processes for dehumidification now being studied by California gas companies. The committee does not recommend any particular method, as its selection will depend almost entirely upon the conditions existing within the individual company. The governing factors may include operating conditions, equipment already on hand, atmospheric and climatic conditions, available space, and allowable investment.

Most of the methods discussed have been successful in other fields, but have not as yet been adapted to the natural gas industry. At least two of the methods have been so adapted, while a plant employing a third process is now under construction in the Ventura field.

Treatment by hygroscopic substances of the huge volumes involved in natural gas transmission is believed unfeasible, due to the large quantities of chemicals required, as well as the impracticability of their revivification. The only absorptive method that has shown promise is one being studied at the present time by the Southern California Gas Co. This method is thought to be adaptable to all gas that passes through absorption plants and depends upon the absorption of the water by absorption oil. The plan, as worked out to date, involves the absorption of water by oil in the towers, the circulation of the oil through the stills and then into

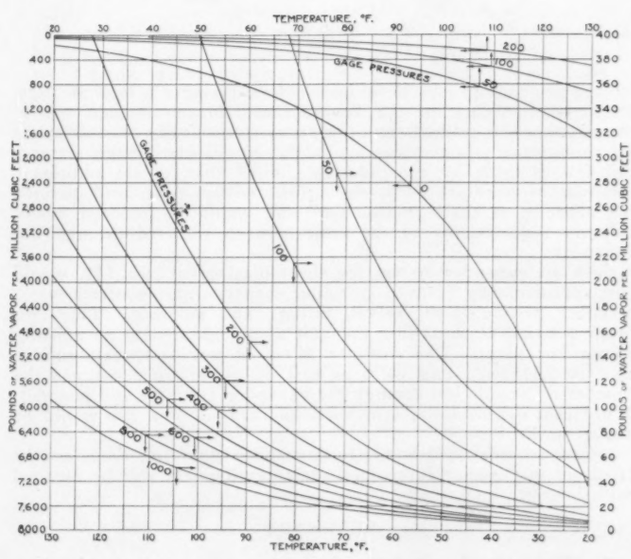


Fig. 5. Water vapor per million cubic feet saturated natural gas at 60 degrees F. and 14.73 pounds per sq. in. abs.

a vacuum chamber, and herein, the water is removed by evaporation. The "dry" oil is then returned to the absorption towers. The "wet" oil would come from the stills at 35 pounds and 350° F. and would contain about 0.3 per cent water by volume. It would enter the evaporator, in which a 10-inch vacuum is maintained by a steam jet. After removal of the water, the "dry" oil, containing but approximately 0.05 per cent water, would again be ready for use. No cost data on this method are available at present.

This process is being tried out on an experimental scale at Kettleman Hills. A small test tower made of 2-inch pipe has been built for this work. Gas from the field, saturated with water vapor, will be made to pass through the tower at an approximate rate of 10-feet per hour with an oil circulation rate of 7 gallons per thousand feet of gas. The operating conditions will be maintained the same as in the large absorbers, namely, a gas temperature of 90° F. and 400 pounds pressure. The oil will be circulated and heated under vacuum to drive off the absorbed water. The water content in the gas, before and after passing through the tower, will be determined, the difference being the quantity removed by the oil. If this method proves practical, a large scale plant will probably be recommended.

Methods for partially removing the water vapor from compressor plant discharge gas depend on lowering, at the plant, the dew point of the gas to a temperature below that which it will obtain at any point in the transmission line. The amount of water to be removed will depend, among other things, on the operating condition of the gas leaving the plant and the ground temperatures along the pipe line route.

The quantities of water vapor contained in saturated natural gas at various temperatures and pressures are shown in Fig. 5. For gas pressures above 200 pounds the scales at the right and bottom should be used, while, for pressures below this figure, the scales at the left and top are employed. This chart is quite useful in dehumidification work. For example: how much water must be removed from gas leaving a plant at 400 pounds pressure and a temperature of 90° F. in order to prevent condensation at any point

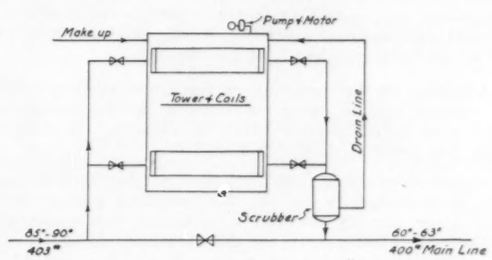


Fig. 6.

beyond the plant? Ground temperature measurements, taken at intervals along the line in the winter season, have shown a minimum of 55° F. To assure no condensation in the line, the gas should be cooled to at least 50°, a margin of safety of 5°. By references to the chart it may be seen that the water vapor content at 400 pounds and 90° is 80 pounds per million feet, while at 400 pounds and 50° it is 21 pounds per million feet of gas. The difference, 59 pounds, is the amount of water vapor that would be removed theoretically under these conditions. The figure of 50° cooling temperature is probably very conservative, as account was not taken of the pressure drop in the line between the plant and the point of minimum temperature.

The committee is indebted to J. S. Fluor of the Fluor Corp. for Fig. 5, as well as much of the cost data contained in this section of our report.

Six methods of obtaining dehumidification on a commercial scale are described in the following paragraphs. They are as follows:

I. Atmospheric cooling.
II. Refrigeration, using ammonia.
III. Refrigeration, using propane.
IV. Vacuum cooling with natural gas jet.
V. Vacuum cooling with a steam jet.
VI. Compression and expansion of total volume of gas.

I. Under certain conditions, atmospheric cooling towers may be used to reduce the amount of water vapor condensing in a pipe line. Charts on operating cooling towers in Southern California show an approach to existing wet bulb temperatures of from 2 to 6 degrees. While this process will remove a large percentage of the water vapor from the gas, it cannot be relied upon to entirely prevent liquid moisture collection, unless the gas is cooled to below ground temperature. A flow sheet for such a process is shown in Fig. 6.

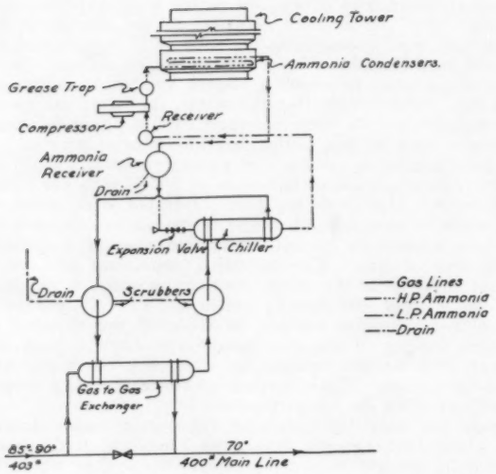


Fig. 7.

The advantages of this method are low initial and operating cost. Cost data for the various methods of moisture removal, herein described, are available for a typical compressor plant with a daily send-out of 30 million feet of gas at 90° and 400 pounds pressure. The initial cost of an atmospheric cooling system is estimated, using present material costs, to be approximately $9,300. This includes tower, concrete basin, tube sections, pumps, motor, scrubber, all piping, wiring, foundations, and painting. Ground space required for this particular sized plant is 50 ft. by 50 ft. The operating cost, including motor power, makeup water, 7 per cent annual depreciation, insurance, taxes, and maintenance is estimated at 0.2 mills per M c.f. of gas treated.

II. Adaption of the ammonia refrigeration process to the cooling of natural gas is being undertaken by the Industrial Fuel Supply Co. at its compressor plant in Ventura. A diagrammatic sketch of this plant is shown in Fig. 7.

The incoming gas at 80°-90° enters a gas to gas heat exchanger wherein it is cooled to 65° by the outgoing gas at 50°. The 65° gas, after passing through a scrubber, enters the ammonia chiller, and is cooled to 50° by the expansion of compressed ammonia. After passing through a second scrubber, the 50° gas is used as a cooling medium for the incoming gas, and finally enters the discharge line at 65°-70°. Equipment for recompressing the ammonia is also shown.

A plant of this type is quite adaptable to companies operating compressor plants because spare compressors are usually available that can be readily changed from gas to ammonia work. The cost of such a system for the typical plant described under atmospheric cooling, see (I), is about $21,750 and includes a gas engine and compressor, condenser, chiller, heat exchanger, two scrubbers, two pumps and motors, a cooling tower and basin, all wiring, piping, painting, as well as an initial charge of ammonia. Ground space required is 50 ft. by 75 ft. Operating costs, including fuel, oil, electric power, water makeup, ammonia makeup, 7 per cent depreciation, insurance, taxes, and maintenance are estimated at 0.6 mills per M c.f. of gas.

The new Industrial Fuel Supply plant is similar to the above, but will handle approximately 50 million feet of gas per day. This plant, completed in July, 1933, embodies the latest in design and includes several automatic features. The unit possesses an automatic by-pass valve which by-passes the entire refrigeration system, should the pressure drop across it exceed 15 pounds. The operation of the valve sounds an electric alarm that will ring until shut off. These precautions are excellent guards against a possible freeze-up of the system. The operation of this plant will be watched with interest.

III. The refrigeration method using propane as the refrigerant, is practically the same in design and equipment as the ammonia plant described above, the difference being that propane is expanded in the chiller unit instead of ammonia. This method depends upon the proximity of a source of propane. As the latent heat of evaporation of propane is much smaller than that of ammonia, it must be obtained at a very low price to warrant its use.

The flow sheet for such a plant is very similar to the ammonia plant shown in Fig. 7. The only plant of this type in operation is the one used to dehydrate the gas entering the Chicago line, located at Fritch, Texas. This plant, with layout, was described in *Western Gas*, June, 1932. It has a capacity of 120 million feet of gas per day and operates at 550 pounds pressure. Its approximate cost was $100,000.

No operating cost estimates for this refrigeration process are available; but it is believed they would run slightly in excess of those given for the ammonia plant.

IV. The vacuum-cooling principle, as it is proposed for adaption to the natural gas industry, depends upon the cooling of the gas to 50° in a heat exchanger by circulation of 45° cooling water. This water has been cooled in a vacuum jet evaporator, shown diagrammatically in Fig. 8. The vacuum jet is operated by taking a small amount, about 3 per cent, of the 400-pound plant discharge gas and expanding to plant intake pressure, 30 pounds. This process, using natural gas, appears quite promising, but has yet to be tried out.

The cost of the typical plant, see (I), using this principle, is estimated at $19,750. This includes all vacuum equipment, cooling tower and basin, two pumps and motors, chiller, exchanger, two separators, scrubbers, and all piping, foundations, wiring, and painting. Use of compressors already on hand, for recompressing the million feet used in the vacuum jet, is assumed. Space required is about 50 ft. by 75 ft. Operating costs, that include recompression of vacuum jet gas, electric power, makeup water, 7 per cent depreciation, insurance, taxes, and maintenance would run about 0.5 mills per M c.f. of gas.

V. A method, practically the same as Number IV, has been proposed, however, using a standard steam jet evaporator instead of one using natural gas. The evaporation unit is similar to the one shown in Fig. 8. A disadvantage, in some localities, is the need for a source of steam.

Initial cost of the typical plant, see (I) to cool gas to 50°, is approximately $14,000. All necessary vacuum equipment, as well as a 90-horse power Scotch Marine boiler with accessories installed, is included. Operating costs are estimated to be 0.75 mills per M c.f., and include steam, electric power, makeup water, 7 per cent depreciation, taxes, insurance, and maintenance.

VI. Compression and cooling of the total volume of gas in an expander unit, with subsequent use of the horse power generated

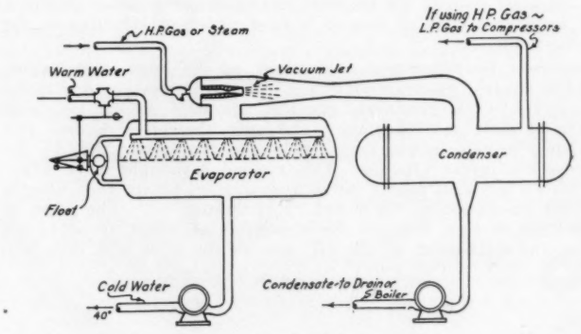


Fig. 8.

by the expanding gas to compress low pressure gas, has been under consideration on the Pacific Coast for some time. It is thought that this method can only prove economically feasible when idle compressor equipment is available. In considering this method, calculations made by one company showed that, unless additional compressors were installed, during the winter peak load periods the capacity of their transmission line would be reduced below delivery requirements by the pressure drop required through the expander.

Such an expander system for the typical plant, see (I), would cost approximately $23,000, including expander unit, concrete work, scrubber, wiring, pipe, valves, fittings, and painting. This estimate is based on installing the unit as an addition to an existing compressor plant. The cost per M c.f. of gas to operate such a unit is 0.54 mills and includes cost of compressing the gas the number of pounds lost through the expander (roughly 100 pounds), 7 per cent depreciation, insurance, and taxes. The gas would be cooled to 50° F.

Other methods of dehumidifying natural gas will, doubtless, be tried out in the near future and their development will be awaited with interest.

SUMMARY

1. The internal corrosion of high pressure natural gas pipe lines is becoming a serious problem in California, practically all of the major fields being involved.

2. Cause of this corrosion is largely due to the action of hydrogen sulphide and oxygen on the pipe, in the presence of condensed water vapor.

3. More rapid and accurate methods of detecting corrosive gas constituents are needed and are being developed at the present time.

4. Considerable headway can be made in corrosion mitigation by a closer control of the oxygen entering pipe lines. This control is dependent largely upon the gasoline and oil companies supplying natural gas and the need for such action, at present generally unrealized, must be impressed upon them.

5. Where oxygen is present in natural gas it can generally be reduced by the stopping of leaks in vacuum-collected gathering systems or elimination of tank vapors. The possibility of taking tank vapors at a slight pressure, instead of at a vacuum, should be investigated.

6. Dehumidification of natural gas appears to be the most practical method of preventing internal corrosion. Numerous methods of accomplishing this at a low cost are available, several using idle equipment already available in most companies.

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LONGITUDINAL MOVEMENTS OF UNDERGROUND PIPE LINES*

The available data on longitudinal movement of pipe lines under actual operating conditions are very meager and the object of this survey is to assemble information gained by various tests and conditions for the purpose of study and comparison with existing theory.

The following article is being presented to show the results obtained in an attempt, by physical test, to measure and determine the amount of longitudinal movement existent in a pipe line subjected to actual operating conditions. The results obtained from the tests attempted, substantiate many of the existing theories.

Due to the fact that temperature is a direct function of the coefficient of expansion, all pipe lines are subjected to expansion and contraction as the temperature varies. If pipe lines were laid on top of ground the temperature variations would cause conditions prohibitive to safe and economical operation unless a large number of expansion joints and an economical means of anchoring were installed. For this reason, more than any other, pipe lines are buried in the ground at a depth sufficient to assure a safe variation in pipe line material temperatures. The correct installation of expansion joints is always a problem pertinent to each individual pipe line installation. The varied conditions existent during construction and operation of a pipe line prohibit the use of any certain rule or formula for determining the correct location of expansion fittings. Many believe that an expansion joint is necessary adjacent to a "cast" fitting, which serves a double purpose in that it relieves the strain on a brittle casting and facilitates the removal of the fitting. However, the somewhat limited tests made for this survey tend to show that many expansion joints could be needlessly installed on straight runs of pipe between fittings.

The first test was made on a section of 22-inch O. D. pipe line, 3000 feet in length near Kettleman Hills, see Fig. 1. The soil in this area consists of a sandy loam and the pipe was buried to a depth of 2 ft. 6 in. The equipment used in making this test was as follows: An expansion joint was installed on each end of this section enabling the line to move longitudinally in the backfill in either direction from the center of the section. Recording thermometers were set as shown in Fig. 1 at four equidistant points along the section. The sensitive portion of the bulbs of these thermometers were immersed in light oil in a jacket welded on the side of the pipe to give as near as possible the pipe metal temperatures. A recording expansion meter Fig. 2 was installed at the downstream expansion joint with one leg on the upstream side of the expansion joint and the other leg firmly fixed on the ground adjacent to the pipe. An indicator was set at a point in the direct center of the section to note movement at this point. The volume of gas flowing through the line during this test was 2260 Mc.f. per hour. A sudden rise in temperature of the gas entering the line was introduced by cutting off the cooling units at the initial points of the section, the results of which are shown in Fig. 3.

Referring to Fig. 3, curves 3, 4, and 5 show an average temperature rise of 21.7 degrees F., affecting the section of pipe over a period of 6½ hours. No movement was recorded at the center of the section and only .02800 inches movement was recorded by the expansion recorder located at the terminal end of the section. Since all movement recorded on the expansion recorder was the result of longitudinal movement from the center of the section, all calculations were based on a length of 1500 feet.

The total elongation of this section to be expected under these conditions if the pipe line was unrestricted can be computed by the formula:

$$E = L \times T \times N$$

Where: E = elongation in inches
L = length in feet
T = temperature change in degrees F
N = coefficient of expansion

Note: Kent handbook quotes value of coefficient of expansion for 20-30 carbon steel having tensile strength of 60,000 lbs. = .0000792 inches per foot per degree.

Substituting values obtained:

$$\text{Elongation} = 1500 \times 21.7 \times .0000792 = 2.57796 \text{ inches.}$$

The results infer that practically all the longitudinal movement with the exception of .02800 inches recorded on the expansion meter was absorbed and restricted by the ground friction or other factors unknown.

In an attempt to determine to some extent the amount of ground friction that could be expected under these conditions the following test was made:

A section of 22-inch O. D. pipe, 40 ft. 0 in. in length was buried (in the same type of soil) to a depth of 2 ft. 6 in. from the top of the pipe to the ground level as shown in Fig.'s 4 and 5. The pipe was backfilled, bulkheaded and carefully tamped the entire length of the backfill with 34 ft. 7 in. of the pipe under cover. By means of a hydraulic jack the pipe was then pushed through the backfill for a distance of 1 inch, see curve No. 1 of Fig. 6. The tamped backfill was then removed and returned to the ditch as loose backfill to the same depth. The same push was made, giving the resultant force curve shown on curve No. 2, Fig. 6. In explanation of the results shown on the curves in Fig. 6 it must be re-

*Sub-Committee Report: F. E. Wilson, chairman, Pacific Gas and Electric Co.

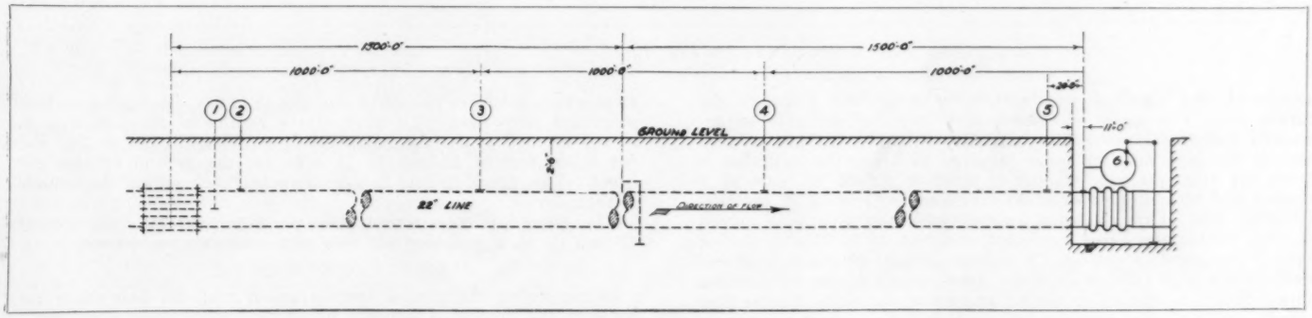


Fig. 1.—Expansionometer.

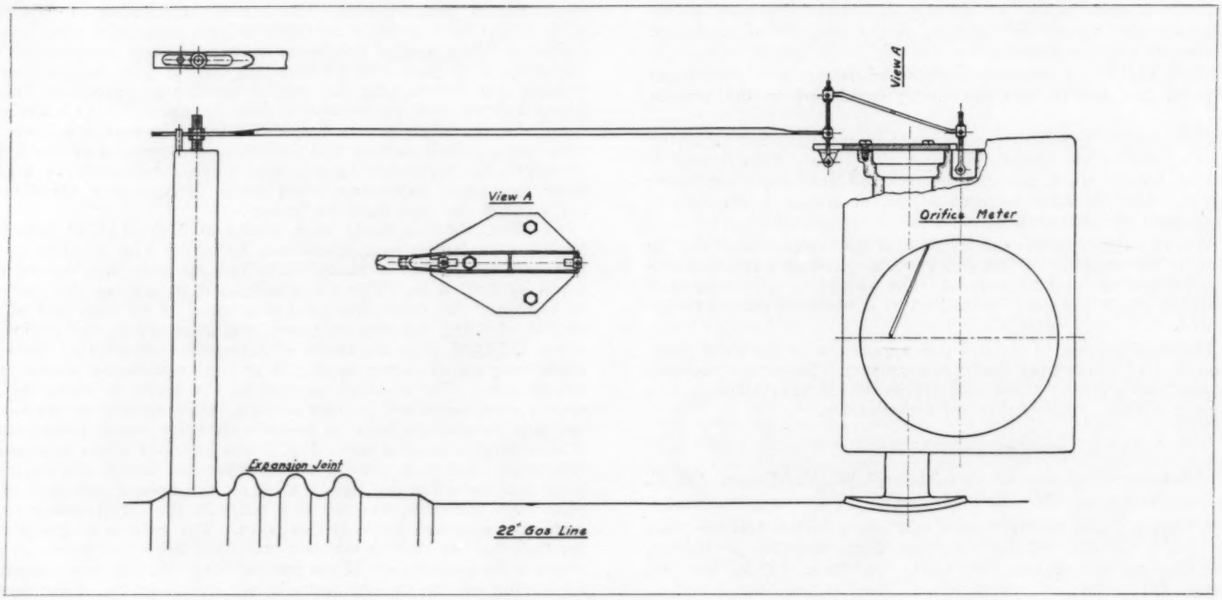


Fig. 2.

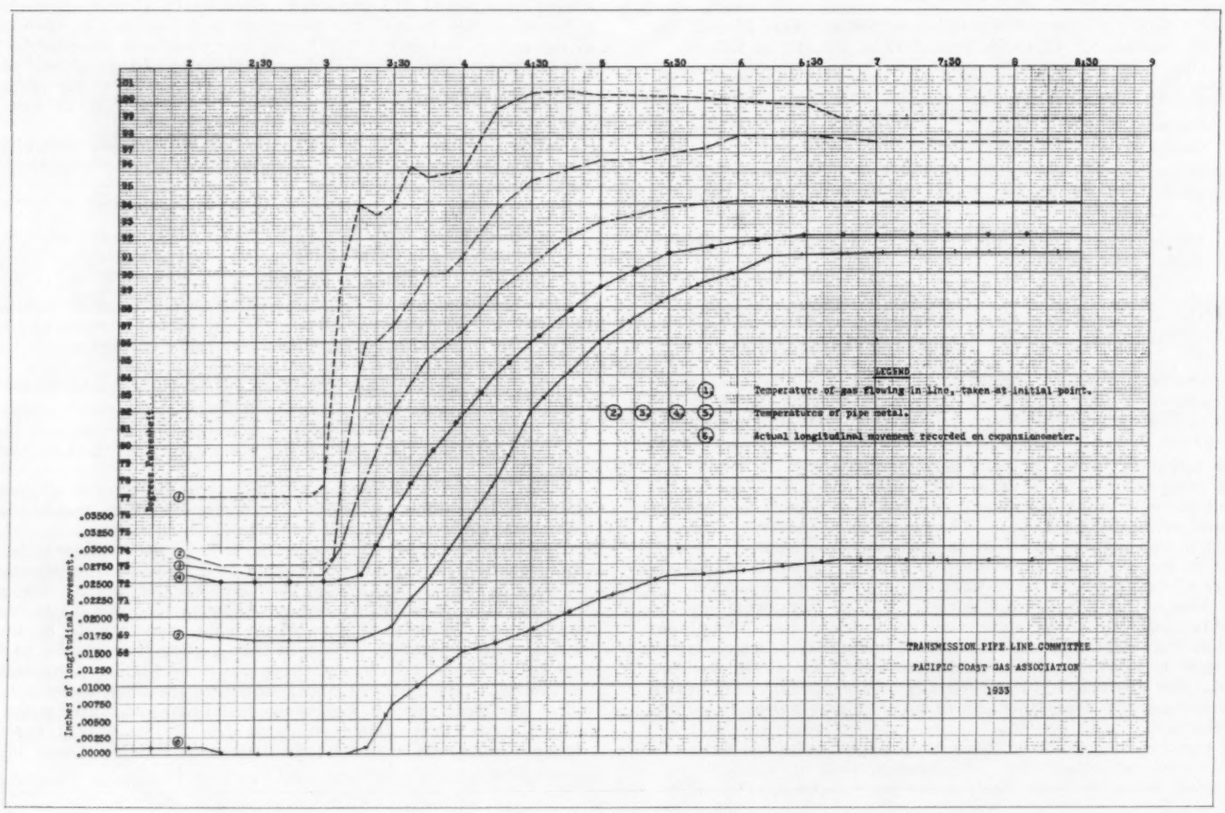

LEGEND
1. Temperature of gas flowing in line, taken at initial point.
2. 3. 4. 5. Temperatures of pipe metal.
6. Actual longitudinal movement recorded on expansionometer.
TRANSMISSION PIPE LINE COMMITTEE
PACIFIC COAST GAS ASSOCIATION
1933
Degrees Fahrenheit.
Inches of longitudinal movement.

Fig. 3.

membered that the soil was extremely sandy and although the curves show practically opposite results they can probably be accounted for as follows: The tamped soil tends to form a pack around the pipe and the force required to break the adhesion is great but after the pipe started to move it played the part of a reamer and created a passage that reduced the friction of the surrounding fill. This condition existed until the pipe was moved ¾ inch where the force remained constant at 9,750 lbs. during further continued movement. The loose backfill of this type of soil establishes a pipe friction from the dead weight of the soil causing an action and a reaction on the entire area of the pipe. As the pipe moved forward, the particles of sand rolled, causing a packing action that reached its maximum at 7/16 inch of forward movement where the force remained constant at 15,825 lbs. during further continued movement. To apply these results to the test, Fig. 1, it was decided to use the minimum figure of 9,750 lbs. or 261 lbs. per lineal foot of 22-inch O. D. pipe for the ground friction existent. This figure is very conservative and well within the bounds of safety.

The ground friction acting upon the pipe over the 1500 feet of 22-inch O. D. pipe under test was then computed as follows:

$$261 \times 1500 = 391{,}500 \text{ lbs.}$$

In comparing the ground friction found with the unit stress existent in this section of line the following results were obtained:

Using the formula: $S = T \times N \times E$

Fig. 4.

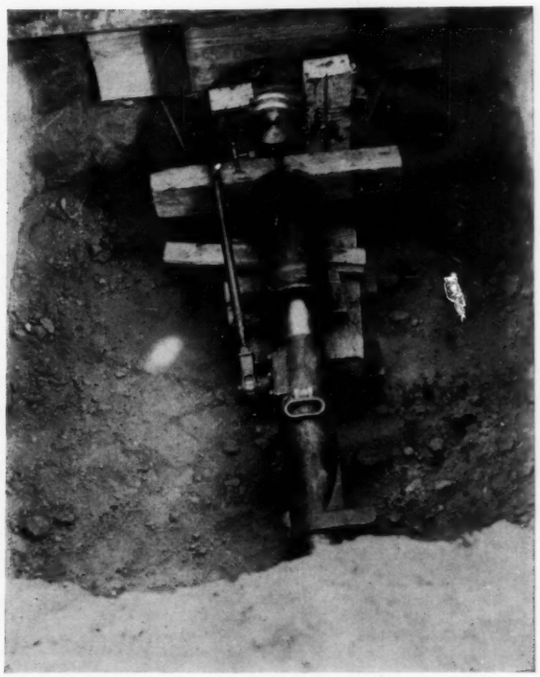


Fig. 5.

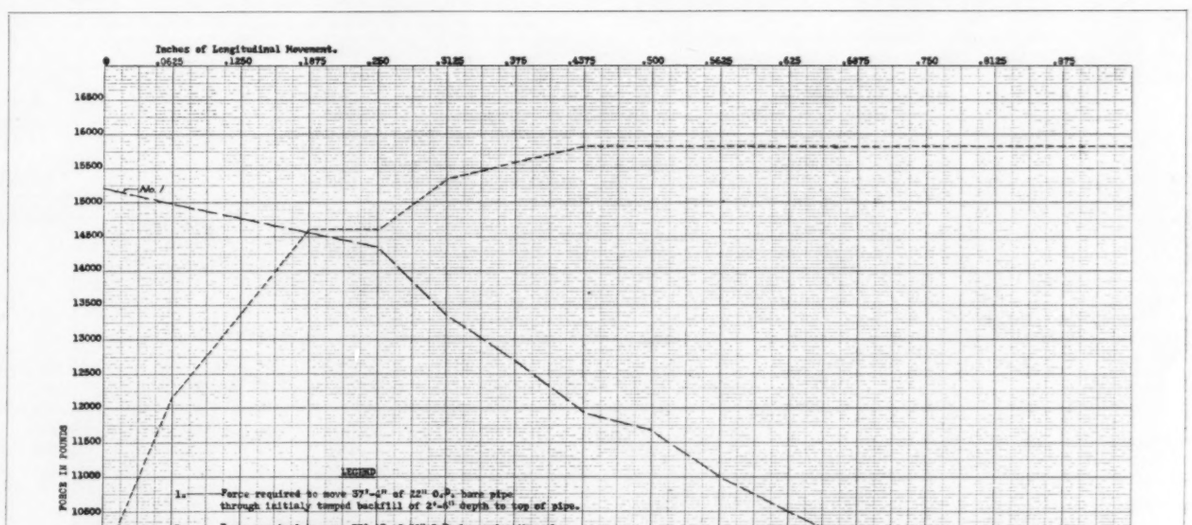


Fig. 6.

Where: S = unit stress in lbs. per sq. in.
T = temp. change in degrees F
N = coeff. of expansion per in. .0000067
E = modulus of elasticity

Hence:

$$S = 21.7 \times .0000067 \times 30{,}000{,}000 = 4{,}491 \text{ lbs. per sq. in.}$$

This would indicate that the unit stress is sufficiently great to overcome the ground friction by several times.

As the elongation recorded by the expansion meter did not show any great movement it was assumed that the greater portion of the movement was absorbed by the elasticity of the metal. Substantiation of this assumption is shown in the formula:

$$E_1 = \frac{P \times L}{A \times E}$$

Where: E_1 = elongation in inches
P = total force in lbs. 391,500
A = area of cross section 21,956 sq. in.
L = length of body in inches
E = modulus of elasticity 30,000,000

$$\text{Hence } E_1 = \frac{391{,}500 \times 18{,}000}{21.9156 \times 30{,}000{,}000} = 10.718 \text{ inches.}$$

The above results indicate that the ground frictional force could resist the forward movement of the pipe through the backfill until the limit of 10.718 inches was absorbed by the elasticity of the metal. Since the total movement or amount of elongation that could be present if the pipe was unrestrained during a temperature rise 21.7 degrees F. is only 2.58 inches, it would seem that there is no danger

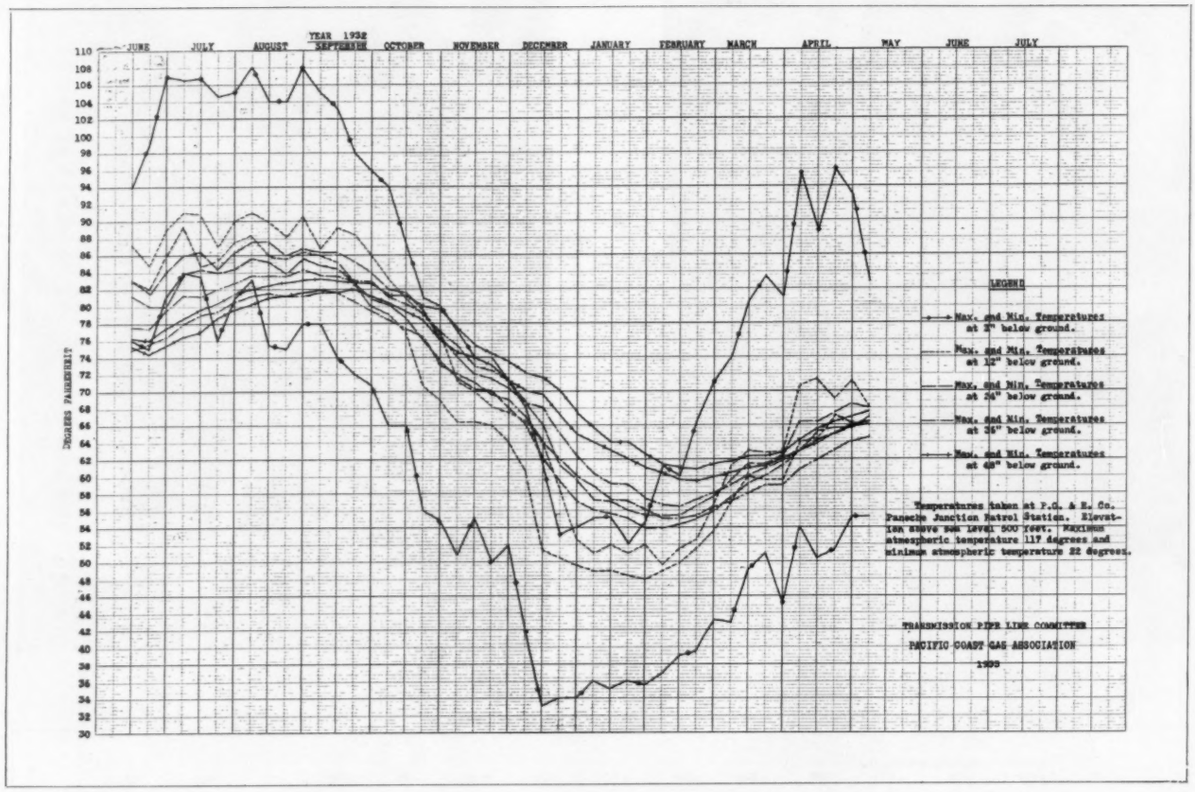

YEAR 1932
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
DEGREES FAHRENHEIT
LEGEND
Max. and Min. Temperatures at 3" below ground.
Max. and Min. Temperatures at 12" below ground.
Max. and Min. Temperatures at 24" below ground.
Max. and Min. Temperatures at 36" below ground.
Max. and Min. Temperatures at 48" below ground.
Temperatures taken at P.G. & E. Co. Panoche Junction Patrol Station. Elevation above sea level 500 feet. MAXIMUM atmospheric temperature 117 degrees and minimum atmospheric temperature 22 degrees.
TRANSMISSION PIPE LINE COMMITTEE
PACIFIC COAST GAS ASSOCIATION
1929

Fig 7.

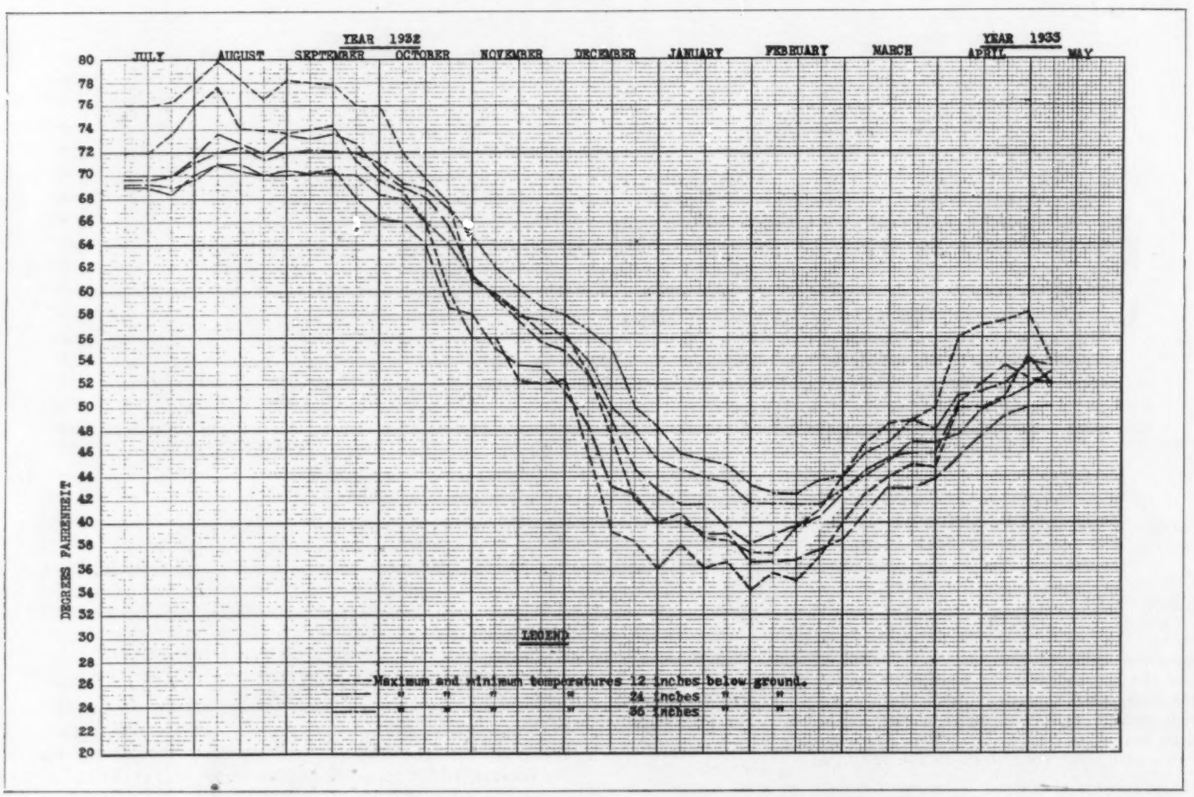

YEAR 1932
YEAR 1933
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
DEGREES FAHRENHEIT
LEGEND
Maximum and minimum temperatures 12 inches below ground.
" " " " 24 inches " "
" " " " 36 inches " "

Fig. 8.

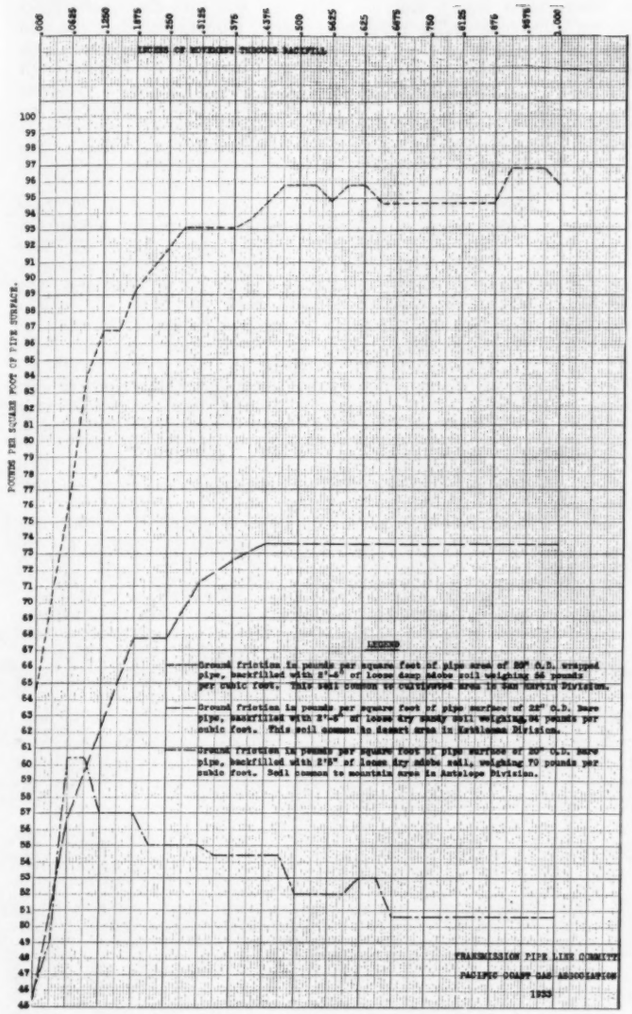


Fig. 9.

of longitudinal movement that would necessitate expansion joints until a change of pipe temperatures of approximately 90 degrees was existent.

The entire length of the 1500-ft. section of line tested was under backfill with the exception of 11 ft. which were exposed in the pit at the expansion meter. By substituting the values existent in the formula for expansion of metal by heat for the 11-foot section:

$$E=L\times T\times N$$
$$E=11\times 21.7\times .0000792=.0188573 \text{ inches}$$

which would indicate that 67.5 per cent of the longitudinal movement occurred in the open span of 11 feet.

These tests substantiate to a great extent the existing theory of: "In using a tube of 60,000 lbs. per sq. in. tensile strength with welds 85 per cent of this figure or 51,000 lbs. per sq. in., and with a factor of safety of 3, expansion joints are not necessary until the temperature range exceeds 85 degrees F. Modern welding practice makes the figure of 85 per cent very conservative and the factor of safety of 3 should be sufficient to take care of the metal fatigue that would be present with continual expansion and contraction near the elastic limit."

In an attempt to find the ground temperature existing at various depths several recording thermometers were installed at various depths for a period of one year (see Fig. 7 and Fig. 8). These curves are self-explanatory; however, it is of interest to note that the maximum variation in ground temperatures recorded at a depth of 36 inches were very comparable at the different elevations. At this depth the temperature range is well within the safety limit, although this record was obtained during one of the most severe years that California has experienced.

Three additional tests were made to determine the coefficient of ground friction of soils loosely backfilled, the results of which are shown in Fig. 9. The various factors that enter into the determination of the coefficient of ground friction values are varied and many can only be determined by actual test; hence these values are only applicable to the particular soils.

In conclusion, it might be stated that only during the period when lines are first placed in operation, while the backfill is still loose, should the results obtained from pipe line tests for the coefficient of friction be used. As lines increase their time of service the ground settles and adheres to the pipe walls to an extent common to the variety of existent soil and the danger of trouble from longitudinal movement decreases.

Large Volume Measurement*

RECORDING THERMOMETERS AS APPLIED TO GAS MEASUREMENT

THIS is an ever-recurring subject, doubt being frequently expressed as to whether the recording thermometers commonly used on gas metering set-ups were yielding the true gas temperatures. Until recent years too few instruments were properly compensated for the effect of ambient temperatures, and very often neither the location nor the method of installation has been ideal.

The idea that an error, even though known to exist in the installation, tends to be compensating, and hence negligible, is difficult to remove. In this connection reference is made to a test conducted by C. E. Pickup of the Southern California Gas Co., at a meter station in Kettleman Hills and presented in the July, 1932, issue of *Western Gas*. No attempt will be made to describe that test but the results clearly show that errors of an appreciable magnitude may exist in any recording thermometer that has not been compensated for ambient temperatures.

L. F. Reetz
Chairman

Whether or not thermometers that are not properly compensated should be replaced with the newer instruments depends upon a number of factors, but generally speaking, any meter set, either orifice or displacement, that is of sufficient importance to have included a recording thermometer in the original equipment is worthy of one that will yield an accurate record of changing temperature conditions.

The results of several tests made during the last year tend to substantiate this statement. The first of these was a test made at Kettleman this spring. The location was the same as that chosen for Mr. Pickup's previous test, four instruments being installed in a 10-inch orifice meter tube, and a comparison made of the results obtained from these instruments. Instrument No. 1 was located 17 feet downstream from the disc, each succeeding one being 6 inches farther downstream. A description of the instruments follows:

Instrument No. 1: Vapor tension actuated, partially compensated, direct connected and installed in well No. 1.

Instrument No. 2: Alcohol actuated, fully compensated, equipped with capillary tubing, and installed in well No. 2 with the sensitive portion of the bulb subjected to line pressure and directly in the flow of the gas.

Instrument No. 3: Gas actuated, compensated with a bi-metallic strip for ambient case temperatures, equipped with capillary tubing, and installed in well No. 3 with the bulb subjected to line pressure and directly in the flow of the gas.

Instrument No. 4: Alcohol actuated, not compensated, direct connected and installed in well No. 4 containing a mercury medium.

A graphical representation of the results produced is given in Fig. 1 in which the records produced from the fully compensated, alcohol actuated instrument are shown as the base temperature to which the others are compared.

This graph shows quite clearly that the non-compensated instruments record temperatures substantially lower than the base temperature while the compensated instruments record practically the same temperatures. If the compensated thermometers are considered as yielding true records of what is actually taking place in the line, it is obvious that measurement based upon older instruments contains a serious error.

In Fig. 2 will be found the records produced from a complete year's comparison of a fully compensated temperature recording instrument and a non-compensated temperature recording instrument. The instruments were located in the same places occupied

*Committee report: L. F. Reetz, chairman, P. G. and E. Co.; C. E. Pickup, So. Calif. Gas Co.; P. E. Beckman, P. G. and E. Co.; Malcolm Miller, So. Fuel Co.; R. M. Stewart, P. G. and E. Co.; Louis Wollenberger, Coast Counties G. & E. Co.; William Johnson, P. G. and E. Co.; E. H. Fisher, Coast Natural Gas Co.

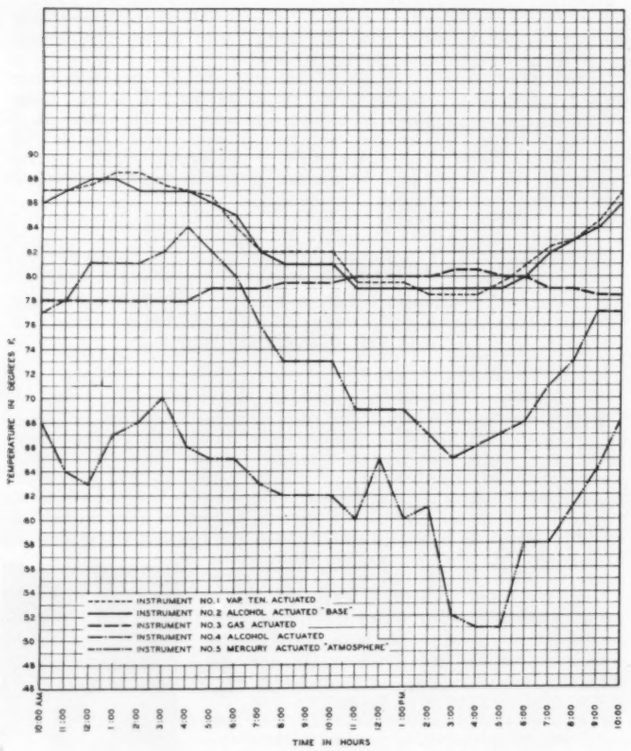

TEMPERATURE IN DEGREES F.
INSTRUMENT NO.1 VAP. TEN. ACTUATED
INSTRUMENT NO.2 ALCOHOL ACTUATED "BASE"
INSTRUMENT NO.3 GAS ACTUATED
INSTRUMENT NO.4 ALCOHOL ACTUATED
INSTRUMENT NO.5 MERCURY ACTUATED "ATMOSPHERE"
TIME IN HOURS

Fig. 1.

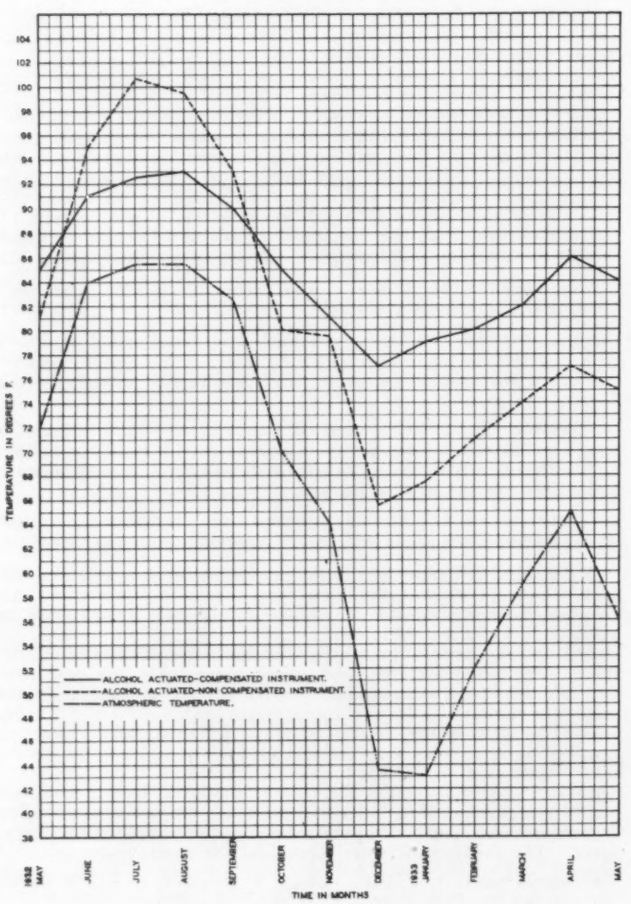


Fig. 2.

by instruments No. 1 and No. 2 in the test just described, these having been removed to permit that test. During the time the two were being compared the atmospheric temperature record shown on the graph was taken from an indicating thermometer located in a shady position adjacent to the set-up. The graph is self explanatory, showing that the non-compensated instrument is decidedly influenced by the atmospheric temperatures. However, attention is called to the fact that the atmospheric temperature was taken in the shade, that temperature being considerably lower than the one to which the meter tube and the instruments were subjected.

The maximum difference occurred during the months of July where a plus difference of 8° F. was shown, and during the month of December when there existed a minus error of 11.5° F. The effective difference in gas volume as compared to computation with the compensated instrument would be 0.8 per cent plus and 1.15 per cent minus. Had these instruments been used with a displacement meter the error would have been about doubled.

A third test made independently and having no connection with the two previously described is shown in Fig. 3. It was conducted for three reasons, first, to discover whether or not the temperatures being recorded on locations adjacent to displacement meters were the true temperatures of the gas in the meter, second, to determine whether the various compensated instruments now on the market required shelter in order properly to record line temperatures, and finally, which of the compensated type would give the most accurate results.

The instruments selected were the following, all of them being, according to the manufacturer, compensated and adapted to the requirements of the test.

Instrument No. 1: Mercury actuated. This instrument was constructed especially for the test and was used to obtain the temperature of the gas inside a 250-lb.-500B Metric meter. It was constructed with a bulb about 12 inches in length and of a diameter that would permit entry through the ¾-inch drain hole at the bottom of the meter. This elongation of the bulb produced a very sensitive instrument.

Instrument No. 2: Gas actuated, capillary tubing, and but partially compensated. This instrument was included in the test as a number of this type are at present in use, and whether or not replacement was advisable was in question.

Instrument No. 3: Mercury actuated, direct connected and compensated.

Instrument No. 4: Vapor tension, direct connected and requiring no compensation.

Instrument No. 5: Alcohol actuated, direct connected and compensated.

Instrument No. 6: Mercury actuated, direct connected and compensated.

Instrument No. 7: Mercury actuated, capillary tubing and compensated.

Instrument No. 8: Atmospheric type recording thermometer.

As the results of the test could be no more accurate than the original accuracy of the instrument each was given a rigid examination prior to installation for the test. All instruments were checked from 33° F. to the limit of their range; instruments No.'s 1, 2, 4, 5, 6, and 7, checked a standard pencil thermometer (which had in turn been checked against a Bureau of Standards calorimeter thermometer) within 1° F. with the room temperature at 75° F.

The case temperatures were then raised to 120° F., a temperature often attained in actual installations. Instruments No. 1 and No. 3 recorded an increase of not over 1.5° F. at both limits of their range. Instruments No. 6 and No. 7 recorded an increase of not over 2° F. under the same conditions. Instrument No. 4 recorded no change under any condition of bulb and case temperatures and verified the manufacturer's statement that the vapor tension type requires no compensation for a change in case temperature. Records produced from instrument No. 5 indicated a variation of not over 1° F. when temperature variations up to 120° F. were applied to the case and this variation corrected itself within 15 minutes of each change, thus producing a visible record of the compensating action.

Instrument No. 2 was equipped with a bi-metallic strip, connected to the spring and pen arm of the gauge, this strip being designed to compensate for changes in case temperature. The tubing was uncompensated except through the ratio of bulb to tubing capacity, about 40 to 1. When tested, this instrument recorded a temperature change of not over 3° F. while the tubing temperature was changed 90° F.; however, a large error was introduced when the case temperature was materially changed. With the case temperature at 75° F. and the bulb temperature at 33° F. the instrument registered correctly. Upon increasing the bulb temperatures the instrument recorded a plus error until at 110° F. the instrument was recording 118° F. The case temperature was then raised to 120° F., while the bulb remained at 110° F., and the instrument recorded 108° F. The bulb temperature was then gradually

lowered to 33° F. while the case temperature remained 120° F. Obviously, temperature recording devices not compensated to a degree of accuracy greater than this should not be used in gas measurement work where ambient temperatures approach the above conditions.

Other instruments checked prior to the actual running of the test were an atmospheric type thermometer and a maximum and minimum Weather Bureau Type indicating thermometer. Both were sufficiently accurate for use in the test.

The meter set-up on which the test was conducted is located near Brentwood, Calif., and during the course of a year is subjected to both very low and high temperatures. The set-up is designed to accommodate two 500B meters and at the time of the test was operating at a pressure of approximately 75 lbs. per sq. in.

Prior to the test one of the side castings of the meter was removed and the maximum and minimum thermometer fastened to the diaphragm plate in a position that would permit reading and resetting by the removal of the hand hole plate at the bottom of the casting. At the same time thermometer No. 1 was installed beside the meter and the bulb located just below the diaphragm and midway between the center partition of the meter and the main casting, but having no contact with the meter other than the point where the capillary tubing passed through the ¾-inch drain hole.

The gauge was then sheltered in a manner that would permit a free circulation of air about the case and checked for several days at the maximum and minimum points against the readings taken from the thermometer fastened to the diaphragm. The two agreed within .5° F. and this established the certainty that the true gas temperature existing at that point in the meter was being recorded. Whether this temperature is that existing in the diaphragm compartments, or the inlet to the meter, is open to question, but there does not appear to be cause for any great change to occur.

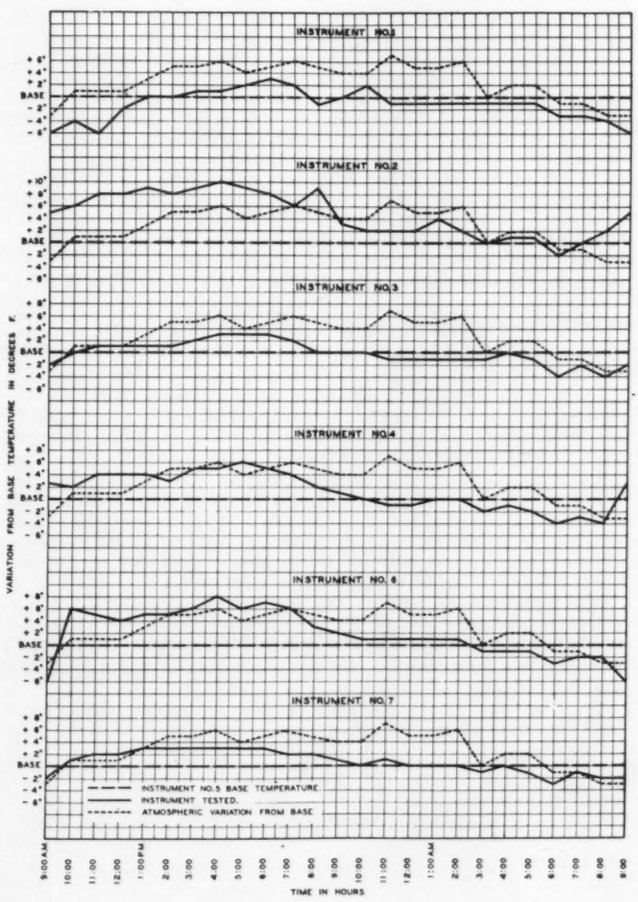


Fig. 3.

The remaining instruments, No. 2 to No. 7 inclusive, were then installed on a 6-inch manifold after the meter, No. 2 being nearest the meter and each succeeding one located about 14 inches farther downstream. The bulbs of the instruments were installed in wells that had been introduced into the pipe through couplings that were welded flush.

Charts were taken for 10 days, during the first five of which the thermometers on the manifold were not sheltered. The results were about what might have been expected from the laboratory examination prior to the test, except that the conduction error from the pipe wall to the well was introduced. All of the thermometers with the exception of instrument No. 5 showed the effect of the heated manifold, the increase in temperature above that being recorded on instrument No. 1 being more marked on those with the larger bulbs. From this it becomes apparent that recording thermometers should be sheltered to reduce the conduction error introduced by the metallic contact between the thermometer bulb and the pipe wall.

The result of the last five days of the test, during which the gauges were sheltered from the direct rays of the sun and yet a free circulation of air permitted around each, were better. These results are given in Table No. 1.

TABLE NO. 1

Inst. No.	*Variation in Range Recorded* ° F.	*Max. Temp. Recorded* ° F.	*Min. Temp. Recorded* ° F	*Ave. Temp. Recorded* ° F.	*Ave. Diff. from Base* ° F.	*Max. Diff. from Base* ° F.
1	35	94	59	76.5	— 0.8	2
2	42	102	60	82.0	+ 4.7	10
3	37	95	58	77.3	0.0	3
4	39	97	58	78.3	+ 1.0	5
5	31	92	61	77.3	.....	....
6	39	99	60	79.4	+ 2.1	7
7	36	95	59	78.0	+ 0.7	3
8	36	97	61	80.2	+ 2.8	5

The results of the test were compared using instrument No. 5 as the base because of the method of compensation used, the location midway along the manifold, and the fact that it appeared to perform better without shelter than any of the others. The results obtained from this instrument should be somewhat higher than those obtained from instrument No. 1 as the atmospheric temperature during the greater portion of the test was above that of the gas.

The results show that instruments No. 2 and 6 are the only two that recorded temperatures substantially different from the base temperatures. However, graph No. 3 clearly indicates that the atmospheric temperature affected the record of the partially compensated instrument No. 2 and that the degree of compensation attained by the various manufacturers varies.

In conclusion, the several tests indicate that the following points should receive consideration by those interested in gas measurement:

(1) All thermometers that have been in service for a number of years should be checked against a modern, fully compensated instrument and replaced if their degree of divergence from the standard, and the quantity metered, warrants.

(2) Shelter should be provided for all types of temperature recording instruments. This is essential, not only to produce undamaged charts, but to approximate the conditions under which the instrument was calibrated.

(3 Any new instruments should be carefully selected with due consideration being given to the conditions under which they must operate, and the degree of their compensation fully known.

(4) All thermometers should be thoroughly calibrated over their entire range when received for a new installation. Although the manufacturers give their equipment close inspection prior to shipment, it is impossible to safeguard against all conditions encountered in transit. In conjunction with this all temperature recording instruments in service should be thoroughly calibrated periodically.

PRODUCTION COMMITTEE

C. P. Johnson, Puget Sound Power & Light Company, Chairman

Natural Gas Standby*

THE substitution of natural gas in areas formerly served with manufactured gas has been far more rapid than has been the ability of the distributor to provide a reliable substitute for the natural gas to insure a continuation of satisfactory service to his customers in case of a shortage or outage of the natural product over which he might have no control.

Only within the past two years has any definite action been taken to develop a satisfactory substitute for use in systems which have been adjusted for natural gas.

J. A. Harritt
Chairman

In 1931 our Association was advised that an ordinary oil gas properly blended with butane and kindred vapors would furnish a fairly satisfactory emergency service. This however, was costly, entailing high production costs as well as excessive capital expenditures, the latter being the most objectionable barrier to this method.

It is imperative that a standby gas supply, which may never be used, or at the most used only spasmodically, shall not constitute a burden through excessive carrying charges.

As a consequence experimentation on the manufacture of a substitute gas in existing oil gas apparatus was conducted in 1932, in San Diego and San Rafael, and a detailed report of the work was presented to this Association at the 1932 Convention by Messrs. Willien, Wills, and Harritt. The work covered by this committee, in 1933, is virtually a continuation and expansion of the previous work.

The process evolved last year for the manufacture of a high heat value, high gravity gas as a substitute for natural, contemplates the use of a light oil or distillate of approximately 32 degrees Baumé, similar to the "gas oil" of the east or the "diesel oil" of the west coast, in any existing oil gas generating apparatus without physical modification.

Methods of generator operation, while fundamentally the same as when making a 550 B.t.u. gas from residuum oils of 16 to 20 degrees Baumé must, of necessity, be modified somewhat to meet the changed conditions and control the quality of the gas produced.

Following the experiments in 1932 further work has been done by the Pacific Gas and Electric Co., the Los Angeles Gas and Electric Corp., and the San Diego Consolidated Gas and Electric Co., former oil gas producers; and numerous experiments are being conducted in the water gas areas of the South, East and Middlewest.

PACIFIC GAS AND ELECTRIC CO.

In December, 1932, the transmission facilities of the Pacific Gas and Electric Co., serving a wide-spread and heavily populated area with natural gas, were taxed beyond their capacity, and it was necessary to start up the plants at San Francisco, Oakland, San Rafael, Vallejo, and Sacramento for the manufacture of 975 B.t.u. gas using Diesel oil as the raw fuel. The San Francisco plant alone had generators of approximately 20 million cubic feet daily capacity in operation. This was the first emergency use of the new oil gas.

Operation was spasmodic and necessarily hurried, with the result that all effort was devoted toward the production of a constant quality of gas and increased capacity of units with but little attempt to gather technical data or create a high degree of operating efficiency.

Although the men were entirely inexperienced in operating under the new method, no difficulty whatever was encountered in the manufacture of the gas nor in maintaining a constant quality.

It was possible to increase the capacity of the generators to about 30 per cent above that obtained when operating on fuel oil for the production of 550 B.t.u. gas.

Such operating data as it was possible to gather from the various plants indicate that an average of about 12 gallons of oil were used per Mc.f. of 975 B.t.u. gas. This includes the oil for heating the checkers.

The sole by-product was tar in the amount of about 2½ gallons per Mc.f. of gas.

The tar emulsion burned well under the boilers and was more than sufficient to supply steam for the plants. No treatment of the tar was required beyond the decanting of surplus free water.

In this case the manufactured gas was used to augment the supply of natural and was mixed with the latter in varying proportions, depending upon load conditions and location. In San Francisco alone certain areas received straight natural gas while contiguous areas received mixtures running as high as 60 per cent manufactured.

During this season the territory served by the Pacific Gas and Electric Company experienced the most inclement weather known in 65 years.

The heavy demand for gas taxed the distribution system and the tremendously increased flow moved forward the accumulations of dust, etc., to the customers' premises. This with the probability that installed appliances were, on the average, entirely inadequate to meet the service demanded of them, resulted in considerable service trouble.

A survey of this service trouble does not indicate that the mixed gas was responsible for unsatisfactory service, as areas which received only natural gas experienced as much difficulty as those recieving the various mixtures.

Quite naturally, the new gas is partially blamed for the difficulties encountered in meeting this unprecedented gas demand and it is unofficially reported that the gas proved unsatisfactory. This report is entirely misleading, as proven by the survey of areas affected by unsatisfactory service during the severe load period.

While the San Francisco plant is well equipped for pyrometric control, this proved to be of no value as a guide in the control of the quality of gas produced. Operators compared the visible characteristics of the effluent tar with calorimeter readings and readily learned how to control their generators by the appearance of this by-product, just as they had formerly controlled operation by the appearance of the effluent lampblack.

This same condition has been encountered in all the later work along this line in former oil gas plants.

LOS ANGELES GAS AND ELECTRIC CORP.

Production Tests

From February 20th to February 25th inclusive, 1933, the Los Angeles Gas and Electric Corp. conducted a series of six tests on the manufacture and utilization of a substitute gas using diesel oil on a generator designed for the use of heavy residuum oil.

Each day represented a different test, as the operating methods and gas values were changed each day in an effort to determine the most satisfactory conditions of operation and the quality of gas most suited to local conditions of utilization, as well as to determine the effect of varying quantities of steam upon the quality of gas produced and its relation to efficiency of operation.

The generator chosen for the test is of the straight-shot, upblast and down-make type, 27 feet diameter by 43 feet high, containing 62,000 standard checker brick. This machine is rated at 4 million cubic feet per day when making 550 B.t.u. gas from low gravity fuel oil.

Fuel oil was used throughout the test in heating the checkers and diesel oil of the following characteristics was used for conversion to gas:

Gravity Deg. A. P. I. at 60 Deg. F.	33.4
Flash Deg. F. Cleveland Open Cup	195.
Fire Deg. F. Cleveland Open Cup	225.
Water	Trace
B. S. & W.	Trace
B.t.u. per pound	19,700
B.t.u. per gallon	140,819
Viscosity, Saybolt at 68 Deg. F.	51
Viscosity, Saybolt at 100 Deg. F.	42
Viscosity, Saybolt at 210 Deg. F.	32
Carbon Residue (Conradson) % by weight	0.08
Sulphur % by weight	0.60
Ash % by weight	0.007
Distillation Deg. F. Initial	422
10%	470
50%	549
90%	649
Maximum	750

*Committee Report: J. A. Harritt, chairman, San Diego Consol. Gas and Elec. Co.; Frank Wills, P. G. and E. Co.; T. N. Kellett, L. A. G. and E. Corp.

Recovery % by Volume at 410 Deg. F.	0
482 Deg. F.	16.5
572 Deg. F.	63.0
662 Deg. F.	91.0
723 Deg. F.	94.3

This oil was atomized with varying amounts of steam on the various tests, except on the 24th, when natural gas was used for atomization in order to determine the relative value of gas and steam as atomizing agents in the finished gas, and in the efficiency of operation.

The test of the 25th was run under varying conditions to check, so far as possible in the shortest time, the capacity of the generator as compared with former oil gas practice.

Manufacturing data are briefly summarized in the self-explanatory Tables, Nos. 1 to 5. Table No. 3 and No. 4 give an indication of the unreliability of pyrometry as a guide to the operation of these large oil gas machines.

Fuel oil used in these tests for heating the checkers only, was of the following characteristics:

Gravity at 60 Deg. F.	17.1 deg. Baumé
B. S. & W.	.9%
Sulphur	1.22%
Flash	193 Deg. F.
B.t.u. per pound	18,600

TABLE NO. 1. GENERATOR OPERATING DATA

Date - Feb.	20	21	22	23	24	25	Total
Average B.T.U.	922	1,000	916	925	900	849	905
Gas Made,M.c.f.	1,481	1,791	1,459	1,381	1,354	4,088	11,554
Make Per Hr. Mcf	185	173	208	180	193	231	200
Gallons Make Oil Used	16,447	20,493	12,981	14,970	13,536	39,732	118,159
Gallons Make Oil Per Hour	2,056	1,984	1,854	1,954	1,934	2,250	2,049
Make Oil, Gals.Per M	11.10	11.44	8.90	10.84	10.00	9.72	10.23
Cu.Ft.Gas per Gal Make Oil	90.0	87.4	112.4	92.3	100.0	102.9	97.8
Gals.Fuel Oil Used	740	1,573	907	909	638	3,094	7,861
Gals.Fuel Oil Per Hour	92	152	225	119	91	175	136
Fuel Oil,Gals. Per M.	0.50	0.88	0.62	0.66	0.47	0.76	0.68
Total Gals.Oil Per M.	11.60	12.32	9.52	11.50	10.47	10.48	10.91
Btu Gas Made Per Gal.Make Oil	82,980	87,000	102,958	85,378	90,000	87,362	88,509
Btu Per Gal Make Oil	140,819	140,819	140,819	140,819	140,819	140,819	140,819
Thermal Efficiency	58.93	61.78	73.11	60.63	63.91	62.04	62.85
M.Cu.Ft.Blast Air Per Heat	217	206	226	145	154	234	199
Heat Period, Minutes	8	8	8	8	8	8	8
Make Period, Minutes	12	12	12	12	12	12	12
Lbs.Steam Usage Per Run:							
Injector Steam	471	491	778	324	7.3*	778	585
Oil loop purge	72	72	72	72	72	72	72
Steam purge	352	352	352	352	352	352	352
Injector by-pass	83	78	83	83	83	83	83
Burner steam	65	65	65	65	65	65	65
Lbs.Steam Usage Per M:							
Injector Steam	7.6	8.5	11.2	5.4	111**	9.4	8.8
Oil loop purge	1.2	1.2	1.0	1.2	1.1	1.0	1.1
Steam purge	5.7	6.1	5.0	5.9	5.5	4.6	5.3
Injector by-pass	1.3	1.3	1.2	1.4	1.3	1.1	1.2
Burner steam	1.1	1.1	1.0	1.1	1.0	0.8	1.0
Total Steam Per M	16.9	18.2	19.4	15.0	8.9	16.9	17.4

* Natural Gas rate 7.3 M.c.f. per run

** Natural Gas rate 111 Cu.ft. per M

TABLE NO. 3. GENERATOR TEMPERATURES

Date—February	20	21	22	23	24	25
Average B.t.u.	922	1000	916	925	900	849
Lower Off-take Avg. Min.	.....	1131	1278	1253	1272	1315
Lower Off-take Avg. Max.	.....	1313	1471	1415	1416	1544
Upper Off-take Avg. Min.	973	994	1183	1157	1174	1243
Upper Off-take Avg. Max.	1218	1169	1375	1275	1308	1326
Bottom Checkers Avg. Min.	1511	1568	1782	1737	1815	1746
Bottom Checkers Avg. Max.	1574	1610	1844	1797	1860	1810
Middle Checkers Avg. Min.	1491	1582	1788	1764	1483	1311
Middle Checkers Avg. Max.	1542	1597	1820	1802	1559	1387
Top Checkers Avg. Min.	1361	1583	1648	1636	1012	1047
Top Checkers Avg. Max.	1464	1669	1740	1687	1114	1146

TABLE NO. 4. GENERATOR TEMPERATURES AND B.T.U.

Time Test Nos.	Lower Off-Take Min.	Lower Off-Take Max.	Upper Off-Take Min.	Upper Off-Take Max.	Top Checkers Min.	Top Checkers Max.	Middle Checkers Min.	Middle Checkers Max.	Bottom Checkers Min.	Bottom Checkers Max.	B.T.U.
A.M.											
5:38			860	1250	1460	1480	1460	1460	1320	1320	930
5:50			920	1360	1520	1560	1480	1500	1375	1385	955
6:10			1030	1360	1570	1650	1510	1520	1430	1450	835
6:30			1130	1220	1620	1720	1520	1530	1440	1450	855
6:50			1040	1130	1650	1780	1530	1540	1400	1440	865
7:10			960	1070	1660	1840	1530	1540	1390	1410	875
7:30			940	1100	1660	1760	1520	1540	1380	1400	880
7:50			950	1110	1630	1760	1500	1520	1370	1380	930
8:10			970	1160	1620	1720	1480	1520	1370	1380	980
8:30			990	1160	1600	1710	1460	1490	1370	1390	1030
8:50			1020	1180	1580	1670	1460	1480	1380	1390	1040
9:10			1020	1180	1560	1640	1470	1480	1420	1440	1030
9:30			1020	1180	1560	1580	1470	1480	1480	1520	1045
9:50	1150	1450	1010	1180	1520	1570	1470	1480	1520	1540	1070
10:10	1125	1425	1040	1170	1480	1550	1470	1490	1560	1600	1105
10:30	1125	1475	1040	1200	1460	1520	1480	1480	1590	1620	1080
10:50	1150	1475	1040	1190	1440	1480	1500	1500	1620	1630	1102
11:10	1175	1535	1050	1260	1420	1460	1500	1520	1660	1670	1103
11:30	1200	1430	1050	1250	1410	1440	1560	1570	1670	1720	1100
11:50	1275	1325	1050	1160	1420	1500	1620	1630	1800	1820	1102
P.M.											
12:10	1175	1240	1000	1090	1420	1490	1620	1630	1820	1880	1090
12:30	1100	1175	1000	1100	1540	1730	1670	1680	1820	1920	1085
12:50	1075	1175	980	1100	1580	1650	1690	1700	1830	1920	1075
1:10	1000	1100	940	1030	1600	1700	1720	1730	1840	1930	1065
1:30	960	1060	920	1010	1700	1850	1740	1750	1760	1900	990
1:50	1025	1125	910	1060	1720	1840	1760	1780	1720	1830	965
2:10	1050	1150	920	1080	1720	1820	1760	1790	1680	1780	975
2:30	1090	1175	940	1130	1760	1880	1770	1800	1650	1730	982
2:50	1150	1400	980	1200	1740	1820	1780	1800	1630	1680	965
3:10	1250	1450	1030	1260	1730	1790	1760	1790	1640	1660	950
3:30	1225	1475	1050	1320	1720	1780	1770	1780	1680	1740	945
Avg.	1131	1313	994	1169	1583	1669	1582	1597	1568	1610	1000

This is a fair average of the fuel oil, or petroleum residuum, used throughout the west, both for heating the checkers and for conversion to gas in the former oil gas method of producing gas up to about 570 B.t.u. The gravity varies, as a rule, between 16 degrees and 20 degrees Baumé.

The tests averaged about 9 hours of operation each day, except on February 25th when approximately a full day's run was made.

The average daily heating value was varied from 849 to 1000 B.t.u., the overall average being 905 B.t.u.

The make per hour varied from 173 to 231 Mc.f. with an overall average of 200 Mc.f. or a daily average of 4600 Mc.f. based on 23 hours per day. This could have been increased under steady operation.

The unsaturated hydrocarbons and the hydrogen vary directly with the B.t.u. and the specific gravity, respectively, all other con-

TABLE NO. 2. CHEMICAL GAS ANALYSIS

Date	2-21-33	2-21-33	2-22-33	2-23-33	2-24-33	2-25-33	2-25-33	2-25-33
Time	10:15 A.M.	3:40 P.M.	12 Noon	12:20 P.M.	12:25 P.M.	7:00 A.M.	10:10 A.M.	4:15 P.M.
Injected with	90 lbs. Stm.	50 lbs. Stm.	90 lbs. Stm.	30 lbs. Stm.	50 lbs. NG	50 lbs. Stm.	50 lbs. Stm.	90 lbs. Stm.
Lbs. Stm. per run	778	471	778	324	0	471	471	778
B.t.u. (Obs.)	1080	970	950	960	940	900	1020	875
Gravity (Obs.)	.745	.690	.660	.662	.625	.580	.675	.570
CO_2	1.8	1.8	2.3	1.8	1.8	1.4	1.7	1.4
Ills.	24.2	19.6	16.7	19.3	15.8	14.5	20.3	13.9
O_2	0.2	0.3	0.2	0.2	0.2	0.1	0.2	0.4
H_2	23.0	29.9	29.8	30.9	28.8	30.5	28.7	34.0
CO	2.8	6.2	4.3	3.7	3.9	2.6	3.6	4.3
C_2H_6	3.8	2.8	3.7	4.0	3.9	1.5	3.8	1.7
CH_4	37.8	38.1	37.5	34.4	42.4	44.0	36.6	37.9
N_2	6.4	1.3	5.5	5.7	3.2	5.4	5.1	6.4

TABLE NO. 5. PURIFICATION OPERATING DATA

Date—February	20	21	22	23	24	25	Average
Temp. after wash Box, ° F.	120	132	146	136	132	150	136
Wash box water, gals. per M.	81	67	47	54	50	42	57
Temp. wash box water, ° F.	73	75	76	76	76	79	76
Temp. before scrubbers, ° F.	99	113	131	120	116	144	121
Scrubber water, gals. per M.	85	92	73	89	81	69	82
Temp. scrubber water, ° F.	73	75	75	76	73	74	74
Temp. after oil scrubber, ° F.	70	64	63	62	61	71	65
Scrubber oil, gals. per M.	13.0	13.4	11.5	13.3	12.4	10.4	12.3
Temp. scrubber oil, °F.	64	63	64	63	63	65	63
*Hydrogen Sulphide							
Before water scrubbers	.....	150.3	126.6	134.5	110.8	87.0	121.8
After water scrubbers	.....	138.5	110.8	154.3	110.8	.....	128.6
After oil scrubbers	.....	142.4	118.7	142.4	122.7	.....	131.5
*Naphthalene							
Before water scrubbers	.....	32.7	.....	55.6	59.6	.....	49.3
After water scrubbers	.....	1.8	5.4	8.5	12.8	.....	7.1
After oil scrubbers	.....	1.3	1.5	2.9	5.8	.....	2.9
*Total sulphur	.....	1.7	6.0	2.1	5.0	.....	3.7
Tar produced in gallons	.....	.....	.....	.....	.....	.....	23,860
Tar produced, gals. per M.	.....	.....	.....	.....	.....	.....	2.1
Tar produced, % of make oil	.....	.....	.....	.....	.....	.....	20.2

* Grains per 100 cu. ft.

stituents remaining fairly constant. Thus the temperature and time of contact which govern so closely the production of these two constituents must be subject to close control to maintain a constant product.

The steam gas reaction throughout the tests was very constant whether the steam input was at the minimum or maximum. Even the atomization by natural gas showed but little change in the carbon monoxide and hydrogen content of the finished gas.

Tar, which is the only by-product, was produced in the amount of 2.1 gallons per Mc.f. of 905 B.t.u. gas. This is an overall average. About 75 per cent was removed in the wash box and the rest in the first two water scrubbers, very slight traces showing beyond that point.

Hydrogen sulphide, naphthalene and total sulphur were far below the average encountered in former oil gas practice.

Compression to 60 pounds with subsequent cooling to 60 degrees F., of 950 B.t.u. gas showed a loss of 20 B.t.u., by calorimeter. The condensed liquid, water, benzine, etc., from this gas after similar compression and cooling was 0.124 and 0.178 gallons per Mc.f. of gas for two respective tests. This shows a satisfactorily stable quality of oil gas, considering the high heat value.

Upon these tests and utilization tests described later the Production Department bases the following conclusions:

1. That a high B.t.u. oil gas can be produced in the existing plant with only a few minor changes, using diesel oil on the "make".
2. That the volumetric capacity of the existing plant can be increased by 20 per cent above that obtained in former oil gas practice.
3. That the benefits of pyrometry are exceedingly doubtful and the best control is by observation of the effluent tar emulsion.
4. That the use of steam beyond 5 pounds per Mc.f. for oil atomization appears to have no influence upon the character of the gas or efficiency of operation.
5. That it is feasible to use natural gas for atomization, but any benefits to be derived, over the use of steam are doubtful.
6. That the tar can be readily dehydrated to form an excellent fuel.
7. That hydrogen sulphide and naphthalene are considerably lower than in the former 550 B.t.u. oil gas, and more easily removed.
8. That the operation of generators on high heating value gas from diesel oil is far more sensitive than former methods, requiring more definite control than formerly.
9. That a much shorter operating cycle with the consequent production of a more uniform gas is possible.
10. That the specific gravity of a 950 B.t.u. gas, viz. .660 is very near that of our natural gas and therefore should not cause any difficulty in distribution or utilization.
11. That a 950 B.t.u. oil gas of .660 gravity is better suited for consumption in natural gas appliances than the higher B.t.u. diesel oil gases previously tested, or other gas tested during this period.
12. That in order to avoid any difficulty in distribution, or losses, or field adjustments of sensitive appliances, the augmentation of the natural gas supply by diesel gas should not exceed 50 per cent.

Utilization Tests

A special appliance testing room was fitted up in which the following representative appliances were installed.

1. Combination water heater burner, horseshoe type, small ports.
2. Water heater burners with 6 Barber tips, baffled.
3. Thermo-storage water heater, horse shoe burner, raised ports.
4. Instantaneous water heater, ring burner.
5. 7-radiant space heater.
6. 10-radiant space heater, 8-bar grids.
7. 6-section tin radiator, pipe burner, two rows of ports.
8. 4-section 6-tube gas-steam radiator, Venturi burner, raised ports.
9. Luminous flame heater, 20 tips.
10. Console range, safety and flash pilots, 4 top burners, one oven burner.
11. 4-burner high oven range, two oven burners.
12. Furnace with electric control, rectangular burner with raised ports.
13. Two dental torches and two bunsen burners.

Both natural and manufactured gas were brought into the appliance room and metered through separate 30-light positive meters properly equipped with regulators to maintain constant pressure and positive proportioning of the gases under test.

The gravity and B.t.u. of each gas and mixture of gases were recorded by a Ranarex recorder and Thomas calorimeter. All appliances were properly adjusted for natural gas and this adjustment was not changed throughout the test.

Each appliance was tested at 3½, 5, 7, 9 and 10½ inches water column and each test covered the following gas mixtures: 100 per cent manufactured, 75-25, 50-50, 25-75 and 100 per cent natural.

The manufactured gases tested straight or mixed with natural were as follows:

Feb. 21	A.M.	1080 B.t.u.	.72 gravity
Feb. 21	P.M.	975 B.t.u.	.695 gravity
Feb. 22	P.M.	963 B.t.u.	.667 gravity
Feb. 23	P.M.	945 B.t.u.	.657 gravity
Feb. 24	P.M.	930 B.t.u.	.612 gravity
Feb. 25	P.M.	805 to 1015 B.t.u.	.58 to .68

In general the flame characteristics and appliance operation using 100 per cent manufactured gas, as compared with natural gas were as follows:

A shorter, sharper flame with a greenish inner cone was apparent. Yellow tips appeared on the flames at 1000 B.t.u.

Below 900 B.t.u. at pressure of 5 inches and lower the flames were too short and would be the cause of poor pressure complaints.

Between 900 and 1000 B.t.u. all appliances operated satisfactorily at all pressures, with the exception of a radiant heater which backfired at pressures of 7 inches and lower on any of the straight oil gases under test. This was corrected in each instance by partially

closing the air shutter which was left full open for natural gas. The luminous flame heater invariably smoked at 9 inches pressure and over on any straight oil gas.

With mixtures of 75 per cent oil gas and 25 per cent natural all appliances worked satisfactorily except a radiant heater which continued to backfire at pressures of 7 inches and lower.

With mixtures of 50 per cent or more of natural gas, all appliances operated satisfactorily and it is doubtful if any but experienced gas men could detect any change in flame characteristics.

The total capacity of the appliances under test in cubic feet per hour of the straight oil gas and the various mixtures was checked against the total capacity when using straight natural gas. As will be seen from Table No. 6 the capacity varied almost directly with the gravity, regardless of the other qualities of the gas mixtures.

As the specific gravity of an oil gas varies directly with the B.t.u., it necessarily follows that in serving a straight oil gas of the same gravity as the natural gas, the difference in B.t.u. input to appliances will vary directly with the difference in the B.t.u. of the respective gases.

Tests were made on the B.t.u. input on all the various appliances, with the various gases and pressures. The results are too voluminous to incorporate here so Table No. 7 only is used to show the general trend. Similar tables for all appliances are available for those directly interested.

SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO.

Production Tests

On April 10th, 1933, a standard Jones generator normally rated at 5000 Mc.f. per day was operated for 10 hours on diesel oil for the production of 950 B.t.u., 0.65 gravity oil gas for testing its adaptability to natural gas appliances. The gas quality was varied from 834 to 1020 B.t.u. for information as to the action of the apparatus under changed conditions.

As noted in previous experimental operation the gas was extremely sensitive to temperature changes in the checkers but the generator was very easily controlled to produce any desired result. There is no reason to believe that this ease of control would not continue over longer periods of operation but on the contrary one would expect improved conditions due to the seasoning of the generator and the experience of the operators.

Diesel engine oil of the following characteristics was used:

Specific Gravity	0.870
Baumé	31.1
Residual Carbon	0.572%
B. S. & W. (centrifuge)	1.00 %
Flash Point	230 deg. F.
Fire Point	250 deg. F.
Saybolt Viscosity	75 deg. F.—57 sec.
	100 deg. F.—46 sec.
	210 deg. F.—34 sec.
Water by Distribution	0.7%
B.t.u. per Pound	19,260
B.t.u. per Gallon	139,500

Ultimate Analysis:

Moisture	0.70%
Nitrogen	0.12%
Carbon	81.71%
Hydrogen	14.14%
Sulphur	0.53%
Oxygen, etc.	2.80%

Fractional Distillations

First Drop	432 deg. F.
5%	464 deg. F.
20%	514 deg. F.
40%	550 deg. F.
60%	594 deg. F.
80%	680 deg. F.
89%	727 deg. F.
96%	Yield
Maximum Boiling Point	727 deg. F.

This oil was used for heating the checkers as well as for conversion to gas. The oil was not pre-heated, and was used at an average temperature of 61 degrees F.

No steam was used during the make period except for oil atomization and for purging out the machine after the make oil was shut off. Otherwise, except for a shorter cycle, the standard methods of operation of the Jones machine when making 550 B.t.u. oil gas were employed.

TABLE NO. 6. TOTAL CAPACITIES OF APPLIANCES IN CUBIC FEET PER HOUR.

Btu and Sp.Gr. of Oil Gas	Mixture Tested %Oil	%Nat.	B.T.U.	Gravity	Water Column 3½"	5"	7"	9"	10½"
		100%	1115	.63	320	384	462	527	562
1080	100%		1080	.72			430	487	522
.72	75	25	1080	.69				487	533
	50	50	1060	.65			439	500	545
	100		1000	.67	300				
	100		975	.69	300	360	426	486	530
975	75	25	1010	.68	302	363	434	492	530
.695	50	50	1045	.66	310	364	439	500	545
	25	75	1085	.64	310	375	450	515	550
	100		965	.67	316	379	450	506	545
963	75	25	1005	.66	318	376	450	504	546
.669	50	50	1040	.65	322	383	456	514	554
	25	75	1080	.64	318	386	455	518	560
	100		945	.66	310	375	450	503	545
945	75	25	995	.65	309	374	450	500	545
.657	50	50	1035	.64	322	381	452	515	547
	25	75	1080	.63	311	380	452	511	560
	100		930	.61	320	391	462	519	575
930	75	25	985	.61	319	389	461	515	565
.612	50	50	1025	.62	317	388	460	513	560
	25	75	1075	.62	320	386	460	514	555
	100		900	.59			461		
805	100		915	.61			460		
to	100		925	.62			453		
1015	100		920	.61			456		
Btu	100		930	.62			456		
	100		950	.64			450		
.58	100		985	.65			444		
to	100		1000	.67		371	439	479	
.68	100		1015	.68		367	435	482	
gravity	100		850	.63			454		
	100		830	.61				520	
	100		820	.59		391			
	100		805	.58		395	475		
	75	25	890	.59			474		
	50	50	990	.60			466		

TABLE NO. 7. TYPE OF APPLIANCE: DAY AND NIGHT THERMO STORAGE WATER HEATER.

Btu and Sp.Gr. of Oil Gas	Mixture Tested %Nat.	%Oil	B.T.U.	Specific Gravity	B. T. U. Input Per Hour 3½"WC	5"WC	7"WC	9"WC	10½"WC
	100		1115	.63	26760	32112	38579	44043	46942
		100	1070	.73					41944
		100	1075	.73				39237	
1080	25	75	1080	.69				39420	
	25	75	1080	.69					43200
.72	50	50	1080	.65					44172
	50	50	1090	.66				40875	
	50	50	1060	.66			34980		
		100	1060	.69			34132		
		100	1000	.67	22500				
		100	975	.69	21938	26325	31103	35490	39488
975	25	75	1010	.68	22826	27472	32926	37168	40905
.695	50	50	1045	.66	24244	28529	34381	39188	42741
	75	25	1085	.64	25172	30489	36565	41881	44811
		100	965	.67	22871	27406	32714	36574	39372
963	25	75	1005	.66	24020	28371	34070	37989	41105
.669	50	50	1040	.65	25168	29848	35568	40040	43160
	75	25	1080	.64	25812	31320	36828	41904	45252
		100	945	.66	21924	25893	32886	35627	38556
945	25	75	995	.65	23084	27164	34626	37313	40596
.657	50	50	1035	.64	25047	29601	36121	39951	42435
	75	25	1080	.63	25164	30780	37692	41364	45360
		100	930	.61	22320	27249	32271	36177	40176
930	25	75	985	.61	23541	28762	34081	38021	41764
.612	50	50	1025	.62	24395	29828	35363	39360	43050
	75	25	1075	.62	25800	31175	37088	41388	43645
		100	900	.59			31050		
		100	915	.61			31567		
805		100	925	.62			31450		
to		100	920	.61			31464		
1015		100	930	.62			31806		
		100	950	.64			32015		
.58		100	985	.65			32800		
to		100	1000	.67		27800	32900	36079	
.68		100	1015	.68		27912	33089	36743	
		100	850	.63			28900		
		100	830	.61				32370	
		100	820	.59		24026			
		100	805	.58		23828	28658		
	25	75	890	.59			31595		
	50	50	990	.60			34650		

Incomplete data due to rapid changes in quality of gas to be tested.

Operating Data

Heat Oil	1,590 gallons
Make Oil	21,222 gallons
Ratio of Heat Oil to Make Oil	1:13.35
Gas Made	1,827 Mc.f.
B.t.u.	945.74
Heat Oil per Mc.f.	0.870 gal.
Make Oil per Mc.f.	11.616 gal.
Total Oil per Mc.f.	12,486 gal.
Cubic Feet per Gallon of Make Oil	86.1
B.t.u. in Gas per Gal. of Make Oil	81,428
B.t.u. per Gallon of Make Oil	139,500

B.t.u. recovery in Gas from Make Oil..... 58.37%
B.t.u. recovery in Tar from Make Oil..... 21.19%
Total recovery in usable form from Make Oil..... 79.56%
Total recovery based on Total Oil..... 74.24%

Calorimeter tests, specific gravity by Ranarex, H_2S tests and analyses were taken as frequently as possible, of the gas entering the relief holder from the generator, all gas for sampling being freed of H_2S in a small portable oxide purifier. Due to the rapid fluctuation in gas quality at this point and the time consumed by various tests, it is impossible to check corresponding results accurately, but the averages are taken as reliable information.

Gas analyses were not made from accumulated samples but from instantaneous samples taken from the flowing gas. Hence they are not truly indicative of actual conditions, as are the averages of calorimeter and Ranarex readings. These tests are as follows:

Time	*Calori-meter*	*Ranarex*	*H_2S per 100 cu. ft.*	*** Pyrometer No. 1*	*No. 2*	*No. 3*
11:30 A.M.	788	.650		1265	1390	1350
50	894	.619		1290	1340	1390
52	906	.622				
12:02 P.M.	924	.670	140 grains	1270	1260	1380
08	985	.660				
12	985	.653				
1:15 *	1012	.602	140 grains	1160	1240	1380
24	1020	.640		1190	1220	1410
48	1008	.645		1180	1220	1430
2:08 *	997	.690	160 grains	1240	1250	1460
25	990	.699		1240	1240	1490
50	985	.690		1250	1220	1480
56	1005	.692				
3:05	988	.695	150 grains	1240	1200	1510
15	955	.685		1280	1210	1530
20	1000	.720				
30	940	.690		1280	1200	1545
40 *	1005	.689		1260	1180	1520
4:03	985	.680	160 grains			
10	982	.680		1280	1190	1560
23	949	.680		1310	1200	1580
30	993	.702				
49	1005	.720		1320	1200	1560
5:04	1017	.680		1380	1200	1600
22	960	.675		1340	1190	1590
38	930	.668		1340	1180	1600
50	912	.651		1340	1180	1600
6:00	962	.650				
17 *	944	.640	150 grains	1350	1210	1610
30	932	.630		1360	1200	1610
45	879	.610				
55	918	.630		1360	1220	1630
7:06	904	.620		1350	1230	1640
13	890	.600				
21	874	.605				
35*	904	.602		1340	1240	1640
47	894	.610		1300	1220	1630
8:04	911	.607	160 grains	1280	1230	1640
30	920	.630		1260	1220	1630
45 *	949	.620		1270	1230	1640
9:02	834	.630		1280	1220	1650
30	920	.649	155 grains	1280	1220	1640
45	908	.645		1280	1210	1650
55	915	.648				
10:20	926	.668				
30	937	.669				
Average	945.74	.6546	152 grains	1285	1224	1530

* Note gas analyses.

** Pyrometer No. 1 is located in the tunnel between the primary and secondary shells. Gas from the primary shell passes over the fire end. No. 2 is located in the gas offtake connection where the fire end contacts the gas from both shells. No. 3 is about midway of the checker pier in the secondary shell. No. 2 should therefore show the mean temperature of gases from both shells. As usual in generator pyrometry, wide discrepancies are noted.

Analyses to compare with the foregoing tests are as follows:

Time	12:55 P.M.	2:10 P.M.	3:40 P.M.	6:20 P.M.	7:30 P.M.	8:40 P.M.	Average
CO_2	2.9	2.9	2.4	3.3	3.6	2.2	3.05
C_6H_6	6.2	6.4	6.3	5.2	5.0	5.2	5.72
C_2H_4	16.2	16.8	16.6	11.3	10.6	13.4	14.15
O_2	0.5	0.6	0.4	0.5	0.2	0.4	0.63
CO	3.3	3.4	3.9	6.2	7.4	5.4	4.94
H_2	19.2	19.4	20.9	27.2	28.1	26.3	23.52
CH_4	49.2	48.2	47.9	42.6	39.8	45.0	45.45
N_2	2.5	2.3	1.6	3.7	5.3	2.1	2.92
B.t.u.	1049	1057	1054	903	864	955	980.30
Sp. Gr.	.714	.712	.704	.650	.656	.647	.680

A test for total sulphur by Referee apparatus extending throughout the period of manufacture showed a total sulphur content of only 408 grains per 100 cu. ft. as against an average of 16 to 20 grains in 550 B.t.u. oil gas made from fuel oil.

By-Products

At about 1000 B.t.u. considerable frothiness of the tar emulsion was noted on the effluent waters. This was due to insufficient cracking. At about 900 B.t.u. indications of lampblack were evident, while at the lower B.t.u. values there was sufficient lampblack to hold the tar in large semi-solid masses. This was due to overcracking.

The gas was passed through the washer, the primary scrubber and three secondary scrubbers in series.

Approximately 75 per cent of the tar was removed by the washer and primary scrubber in about equal proportions. The rest was removed in the first secondary scrubber, while the second and third secondary scrubbers removed naphthalene only, in small quantity.

Except for short periods when lampblack was produced, the tar was very fluid and heavy, settling out readily in the tar separators.

During the two days following the manufacturing period, the tar emulsion was pumped from the separators into the storage tanks and a decanting sump. After pumping it appeared that separation would be difficult, but by heating the contents of the tanks to about 100 degrees F. the free water came readily to the surface, the dividing line being very distinct. The emulsion, collected from all apparatus, seal pots, etc., totalled 7500 gallons.

This emulsion consisted of 44.4 per cent water. Thus the total tar produced was 4170 gallons, or 2.28 gallons per Mc.f. of gas or 19.65 per cent of the make oil.

Specific Gravity of Tar..... 1.123 at 60 degrees F.
B.t.u. per pound 16,070
B.t.u. per gallon.....150,454

This emulsion was burned under a 500 H.P. B. & W. boiler operating a few hours daily. The emulsion was heated to about 190 degrees F. in the boiler room and was atomized by steam for burning. It flowed through the burners almost as smoothly as fuel oil and it appeared that it might support its own combustion in a highly heated furnace. It would not do so during the short periods of operation experienced and it was necessary to keep an oil burner in operation as a pilot light.

Quality and Utilization

The gas made was stored in a 2000 Mc.f. holder, from which it was drawn into the relief holder and there mixed with natural gas in the following proportions: 25-75, 50-50, 75-25, after which no natural was added but straight diesel gas was sent out on the line.

The line chosen for the test was a 6-inch high pressure line about 16 miles long, serving several suburban communities with a total of about 3500 meters and a very fair representation of the average gas usage, there being both large and small consumers with both modern and antiquated appliances, using about 310 Mc.f. per day.

The mixed gases and straight diesel gas sent to this line were subjected to compression to 30 pounds gauge.

All tests on the sendout gas both in the laboratory and appliance testing room were on gas taken from the main after compression to 30 pounds and subsequent reduction to inches water column.

Appliances at the plant for checking the utilization of the various mixtures at various pressures consisted of.

Plant laboratory	1 gas-steam radiator
Plant calorimeter	4 radiant heaters
Specific gravity recorder	2 radiant heater burners
2 open top ranges	4 floor heaters
1 submerged oven range	1 central hot air furnace
1 smooth top range	2 water heaters

and several types of skeleton water heater burners.

In deflating the holder for the storage of diesel gas, 96 Mc. f. of natural gas was left in the holder crown. Thus the diesel gas

under test contained 5 per cent of natural, assuming the two gases to have blended properly.

On April 12th the gas being drawn from this holder tested as follows:

B.t.u. 931.3
Gravity .644

This gas was mixed with natural in a 25-75 proportion at 9:30 A.M., April 11th and sent out for two days. No complaints were received and some statements were made that the gas burned better than the natural.

No difficulty whatever was experienced with any of the appliances in the test room at the various pressures on this mixture, the men in charge stating that the gas was more flexible and the flames slightly more condensed and firm and approximately of the same size and color as natural gas. None but an experienced gas man could have detected any change whatever.

The mixed gas being supplied was 1036 B.t.u. and .655 gravity, this being an average of seven readings.

At 8 A.M., April 13th, a mixture of diesel and natural gas in equal proportions was turned into the district under test. This gas was of 999.5 B.t.u. and .648 gravity, averages of nine readings.

No complaints whatever were received from the various customers.

Diesel gas drawn from storage on April 13th tested as follows: B.t.u. 929, gravity .638; and on April 14th B.t.u. 917, gravity .639, averages of five readings.

The gas sent out on the line on April 14th, a 50-50 mixture as measured into the holder, was of 998 B.t.u. and .648 gravity, an average of eight readings.

It will be noted that a decreasing B.t.u. was obtained on the various withdrawals of diesel gas from the storage holder.

This is checked by partial analyses which show a decrease in the C_6H_6 content in accordance with the lapse of time since manufacture. The C_6H_6 apparently condensed upon standing in the holder as follows:

April 10th *5.7 per cent (entering relief holder)
April 11th 3.6 per cent (from storage holder)
April 12th 3.2 per cent (from storage holder)
April 13th 2.6 per cent (from storage holder)
April 14th 2.6 per cent (from storage holder)

after which it remained constant, as did also the B.t.u. by calorimeter.

It is apparent that the C_6H_6 content must be held down in commercial operation to avoid losses.

The serving of the 50-50 mix was maintained for four days. At the end of this period no complaints whatever had been received and service men reported conditions highly satisfactory.

At 8 A. M. April 17th the mixture of gas on the line was changed to 75 per cent diesel and 25 per cent natural.

Diesel gas drawn from storage April 17th tested as follows: 915.6 B.t.u. and .642 gravity, average of four readings.

The gas served on April 17th was of 968.6 B.t.u. and .641 gravity, an average of 10 readings; and on April 18th, 953.5 B.t.u. and .634 gravity, an average of 15 readings.

No complaints of any nature were received and no re-adjustments were made, although the weather suddenly turned cold and wet on the evening of the 17th, continuing so through the 18th, 19th and 20th with a corresponding increase in gas required.

At 4 A. M. on the 19th straight diesel gas was turned into the line. Tests were as follows: B.t.u. 919.8 and gravity .634, an average of 15 readings.

Seventy-one service calls were received on the 19th and 20th. This represents about 2 per cent of the customers receiving the diesel gas. These calls are roughly classified as follows:

Seventy-five per cent due to local conditions which would have necessitated calls over a period of a few days, regardless of the quality of gas being served, and 25 per cent which might be partially attributed to the changed gas. Of these latter only three customers were definitely unable to secure a passable degree of service from the diesel gas, viz: torches and sterilizer in a dental office, sterilizer in a hospital and one burner in a chicken brooder. These are all special equipment and are very sensitive under any condition and required re-adjustment for the diesel gas. They gave satisfactory service after air adjustment. A few radiant heaters also required air adjustment when cold but when heated, the former natural gas adjustment was resumed without difficulty.

The straight diesel gas supplied on April 20th was as follows: 932.4 B.t.u. and .64 gravity, an average of 11 readings.

It will be noted that the heat value and specific gravity of the diesel gas increased on the last day of the test, April 20th.

Due to the deflation of the diesel gas holder, there was a differential pressure of 8 inches water column across a 30-inch gate valve separating this holder from the natural gas holder, which apparently allowed a leakage of natural gas into the compressor suction. The leakage apparently amounted to about 1 per cent of the gas sent to the line under test, or 3 M.c.f.

Straight diesel gas was served for 32 hours and the test was stopped due to the exhaustion of the supply.

Throughout the eight days of serving mixed gas, whether of 25, 50 or 75 per cent diesel gas and with the various pressures used in the appliance tests, there was a surprisingly similarity of flame characteristics and burner action. Slightly firmer and slightly shorter cones could be detected by experienced men, but would have escaped notice by probably 90 per cent of users.

The straiight diesel gas flame was more easily detected due to a slightly shorter, firmer and bluegreen cone and a less feathery flame above and around the cone.

No backfiring occurred in the test room and no flames lifted from the ports though pressures were varied from 2 to 14 inches water column, with the exception of some of the radiant heater burners, which backfired occasionally when cold, at 2½ inches pressure, but not above that pressure while using any of the gases under test, nor after they became heated.

From this experiment the following conclusions are drawn:

1. That a high heat value, high gravity oil gas interchangeable with natural gas can be manufactured in any standard oil gas generator without structural changes of any kind, using diesel engine oil or similar oil as the raw fuel.
2. That the volumetric capacity of the plant can be substantially increased.
3. That the thermal capacity of the plant can be increased in greater than direct proportion to the increase in B.t.u. of the gas made.
4. That the cost of production on a thermal basis will be definitely less than the cost of 550 B.t.u. gas from fuel oil, assuming a reasonable price differential between the fuel oil and the diesel oil, such as exists at present.
5. That the by-product (tar) will be of more value and entail less expense in handling than the former tar and lampblack, becoming an asset rather than an expensive nuisance.
6. That in case of a permanent failure of natural gas, this gas merits consideration before a return to former practices.
7. That a gas of 925-950 B.t.u. and .64-.65 gravity appears ideally adapted to our conditions.
8. That the unsaturated hydro-carbons in a richer gas constitute a loss to the manufacturer with no appreciable advantage gained by the customer.

Utilization Tests

Comprehensive studies were made on the various appliances under test in the laboratory, without any changes in the natural gas adjustment. These are available to those who are directly interested, but are too voluminous to use here. The following observations and tables were picked at random to indicate the general trend of the tests and the results:

With 25 per cent oil gas and 75 per cent natural the flame was quite sharp and pale blue with red spots above the corona. There was no blowing away from the ports as occurs with natural gas on cold burners. The ignition speed was greater and burners lighted fully and rapidly. The average burners would easily take up to 8 inches pressure whereas the maximum allowable with natural gas was 7 inches.

With the 50-50 mixture the flame was less sharp and more nearly comparable to that of natural gas. The burner lighted more readily than with the 25-75 mixture. Efficiency tests were slightly less favorable to the 50-50 mixture than to the 25-75 mixture, but still better than with natural gas. All efficiency tests were favorable to the oil gas whether mixed or straight.

With the 75-25 mixture the flames were clean cut with a distinct corona and a red tinge. All burners operated satisfactorily at from 3½ to 8 inches pressure.

With straight oil gas of 920 to 932 B.t.u. and .634 to .64 gravity all appliances burned satisfactorily at pressures of 2½ to 8 inches, except a radiant heater which backfired, when cold, at the lower pressure.

Rutz lighters worked exceedingly well on this gas.

On a mantle light, dark spots were noted on the mantle with oil gas at all pressures.

There is no combustion odor to this gas as compared to that of natural gas, where it is particularly noticeable on enclosed burners.

All appliances under test were properly adjusted for natural gas at 6 inches pressure and from the foregoing observations it is assumed that this oil gas is more flexible in utilization than the natural gas.

With a high proportion of oil gas in the mixture or with oil gas straight a change in flame characteristics would be noticeable, namely a shorter, more clean-cut cone, and a less ragged flame.

Throughout the tests the volumetric input to the various appliances remained practically unchanged.

Therefore the B.t.u. input varied almost directly as the B.t.u. value of the respective gases, as shown in Tables Nos. 8, 9 and 10.

*This is undoubtedly too high for an average, as proven by the fact that analyses show higher B.t.u. and gravity than do the calorimeter and Ranarex.

TABLE NO. 8. AUTOMATIC INSTANTANEOUS WATER HEATER
9 Orifice No. 54 M.T.D.

				Pressure In. W. C. and B.t.u. Input				
% Oil	*% Natural*	*B.t.u.*	*Gravity*	*3½ in.*	*5 in.*	*7 in.*	*9 in.*	*10½ in.*
	100	1105	.635	72333	82013	99450	112047	121660
25	75	1000	.648	64280	78000	92000	104000	112000
50	50	1002	.648	62400	74227	89800	100200	109900
75	25	952	.635	61308	71400	85680	96532	103863
100		925	.635	59177	68281	83610	94200	101353

100 per cent Natural Gas: 3½ in.—Fairly sharp blue flame. 5 in.—Same only longer, slight tinge of red. 7 in.—More red than at 5 in. 9 in.—Flame pulling away, bad odor, red tinge. 10½ in.—Very bad odor, pulling away more pronounced, more red and yellow, flames coming out top of heater. Lights and burns well from 3½ in. to 7½ in.

25 per cent Oil—75 per cent Natural: 3½ in.—Very sharp light blue flame. 5 in.—Sharp but longer. 7 in.—Sharp blue with slight tinge of red. 9 in.—Sharp and longer, more red tinge. 10½ in.—Hazy flame with excess red tinge, no yellow. Flame coming out top of heater. Lights and burns well from 3½ in. to 8 in. Not as much odor as 100 per cent natural gas.

50 per cent Oil—50 per cent Natural: Practically the same as above test excepting there was not as much combustion odor. Lights and burns well from 3½ in. to 8 in.

75 per cent Oil—25 per cent Natural: 3½ in.—Fairly sharp light blue flame. 5 in.—Fairly sharp but longer. 7 in.—Not as sharp, longer, slight red tinge, performance like 5 in. on 100 per cent natural gas. 9 in.—Hazy cones and red tinged with yellow, slight odor. 10½ in.—Very poor flame but not as bad as 100 per cent natural gas at this pressure. Lights and burns well from 3½ in. to 9 in.

100 per cent Oil Gas: Performance very much like 100 per cent natural gas but no so much odor, not so much red or yellow at respective pressures. Flame at 7 in. pressure looks like flame on 100 per cent natural gas at 5 in. Lights and burns well from 3½ in to 9 in.

Results of Efficiency Test:

Natural Gas	65.1%
25% Oil—75% Natural	73 %
50% Oil—50% Natural	71.3%
75% Oil—25% Natural	66.6%
100% Oil	70.1%

TABLE NO. 9. SMOOTH-TOP RANGE—FRONT BURNER
Orifice No. 55 M.T.D. Burner Ports—48 No. 30 M.T.D.

				Pressure In. W. C. and B.t.u. Input				
% Oil	*% Natural*	*B.t.u.*	*Gravity*	*3½ in.*	*5 in.*	*7 in.*	*9 in.*	*10½ in.*
	100	1105	.674	7415	9191	10608	11602	12376
25	75	982	.642	6958	8312	9212	10687	12164
50	50	998	,648	6986	8283	9371	10756	12151
75	25	974	.642	6720	7986	8990	10032	11590
100		915	.632	6313	7411	8875	9790	10614

100 per cent Natural: 3½ in.—Fairly sharp small blue cones. 5 in.—Longer and sharper cones. 7 in.—Slightly hazy cones, slight floating condition. 9 in.—Hazy flame, red tinge, no yellow, floating worse. 10½ in.—Very poor flame, floating worse, bad odor. With all burners lighted and lids on is dangerous above 9 in. Good results up to 6 in. Lighted and burned well when cold or hot.

25 per cent Oil—75 per cent Natural: 3½ in.—Very sharp small blue flame. 5 in.—Sharp light blue flame, longer than at 3½ in. 7 in.—Sharp light blue flame, longer than at 5 in. but shorter than at 5 in. on 100 per cent natural. 9 in.—Sharp blue flame, longer than at 7 in. 10½ in.—Appearance of flame like a very lean adjustment of 100 per cent natural gas at 5 in. No indication of floating or pulling away from 3½ in to 7 in. with all burners lighted and lids on but above 7 in. bad odor and bad floating condition. Lighted and burned well when cold or hot from 3½ in. to 7 in. W. C.

50 per cent Oil—50 per cent Natural: 3½ in.—Sharp, short blue flame, not as sharp as above test. 5 in.—Fairly sharp blue flame, longer. 7 in.—Slightly hazy and longer flame. 9 in.—Hazy blue flame. 10½ in.—Slight floating hazy flame, no yellow but tinge of red. Lights and burns well up to 7 in. when cold or hot.

75 per cent Oil—25 per cent Natural: 3½.—Fairly sharp blue flame. 5 in.—Slightly longer, more like the appearance of 100 per cent natural gas. 7 in.—Flame longer and sharper than at 5 in. 9 in.—Burner appears like 100 per cent natural gas at 6 in. 10½ in.—Hazy blue flame with excess red but no yellow. With all burners lighted and lids on slight pulling away when cold up to 7 in. Can be operated up to 7 in. as compared with 6 in. on 100 per cent natural gas.

100 per cent Oil Gas: Sharp blue flame throughout. Lights and burns satisfactorily when sold or hot from 3½ to 9 in. Flames appear very much like 100 per cent natural gas but slightly shorter and sharper. 3½ in.—Sharp blue flame. 5 in.—Sharp and blue, longer. 7 in.—Longer with tinge of red.—9 in.—Not so sharp and slightly longer, still a good flame.—10½ in.—Still shows with red tinge. With all burners lighted and lids on can be operated at 8 in. as compared with 6 in. of 100 per cent natural gas.

TABLE NO. 10. SMOOTH-TOP RANGE
Oven burner with oven control
Orifice No. 43 M.T.D. Burner Ports—115 No. 41 M.T.D.

				Pressure In. W. C. and B.t.u. Input				
% Oil	*% Natural*	*B.t.u.*	*Gravity*	*3½ in.*	*5 in.*	*7 in.*	*9 in.*	*10½ in.*
	100	1105	.674	21216	25083	29282	33150	35470
25	75	982	.642	17694	20643	25288	29550	34169
50	50	996	.648	19621	22432	25922	30308	34001
75	25	974	.642	17892	21915	25518	29190	31817
100		920	.635	17848	21068	24840	28060	30268

TABLE No. 10—(Continued)

100 per cent Natural: Lights and burns OK when hot or cold with fairly sharp blue flame, with slight red tinge at end of flame from 3½ in. to 9 in. Above 9 in. slight pulling away at extreme ends of burner, not bad however. Very good flame on by-pass from 2 in. up to 10½ in. 3½ in.—Short fairly sharp and blue. 5 in.—Longer flame, slight red tinge. 7 in.—Longer and slightly hazy, more red tinge. 9 in.—More hazy, more red, but not bad. 10½ in.—Longer, more hazy, more red, still good. Slight pulling away when cold or hot.

25 per cent Oil—75 per cent Natural: Lights and burns OK when cold or hot on pressure from 3½ in. up to 10½ in. 3½ in.—Very sharp light blue small flame. 5 in.—Longer sharp light blue. 7 in.—Longer sharp blue, very slight pulling of one or two ports at ends of burner. 10½ in.—Not as sharp, but very good flame. Very good flame on by-pass from 2 in. to 10½ in.

50 per cent Oil—50 per cent Natural: Lights and burns OK when hot or cold with more of a red tinge than the 25-75 per cent gas. At pressures from 3½ in to 10½ in. there is no pulling or floating, no perceptible odor. Burns well on by-pass from 2 in. to 10½ in. Flame character not as sharp as 25-75 per cent mixture.

75 per cent Oil—25 per cent Natural: Lights and burns OK when hot or cold at pressures up to 9 in., flame not as sharp as 50-50 per cent gas. At 7 in. flame looks like 100 per cent natural gas at 5 in. pressure. At 9 in. flame is like 7 in. of 100 per cent natural gas. 10½ in.—Still a good flame, more red but no yellow. By-pass flame good from 2 in. to 10½ in.

100 per cent Oil Gas: Lights and burns OK when hot or cold on pressures from 2½ in. to 9 in. (as compared to 2½ in. to 7 in. on 100 per cent natural gas). Flame not as sharp as 25-75 per cent gas. Has red tinge at end of burner but no yellow. Good blue flame on by-pass from 2½ in to 10½ in. Flame character more like 100 per cent natural gas than the above tests, but slightly sharper. No perceptible floating, pulling away or odor.

TABLE NO. 11. EFFICIENCIES OF THE VARIOUS GASES

Instantaneous Water Heater:	
Natural Gas	65.1%
25% Oil—75% Natural	73.0%
50% Oil—50% Natural	71.3%
75% Oil—25% Natural	66.6%
Oil Gas	70.1%
Instantaneous Water Heater:	
Natural Gas	62.1%
25% Oil—75% Natural	67.3%
50% Oil—50% Natural	68.8%
75% Oil—25% Natural	65.9%
Oil Gas	68.0%
Water Heating on Open Top Range Burner:	
Natural Gas	33.8%
25% Oil—75% Natural	36.2%
50% Oil—50% Natural	35.7%
75% Oil—25% Natural	34.3%
Oil Gas	34.7%

Eastern Experiments:

In the former water gas areas gas engineers are faced with the problem of a substitute gas as were we on the Pacific Coast.

Water gas apparatus does not lend itself so readily to the manufacture of a stable high heat value, high gravity gas as does our oil gas apparatus and their problem is somewhat more complex than ours. The apparently simple expedient of high carburetion does not solve the problem satisfactorily. High carbureting by under-cracking the oil, results in an unstable oil gas, condensible under distribution conditions, compression, etc., with a consequent depositing of light oils and gum-forming ingredients in the system.

So far as we can learn, the tendency is leaning toward a straight oil gas as a substitute for natural.

The first commercial installation of which we have note, is the remodelling of the Denver, Colorado, water gas machines for the manufacture of gas under the Refractory Screen Process developed by the Combustion Utilities Corp. This process has been fully described in the technical press, and will not be discussed here.

Experimental work on a large scale, with this process, is under way in Denver and is being watched with interest by the industry at large.

An interesting report was submitted at the A.G.A. conference in New York, May 22 and 23, by E. S. Pettyjohn, research engineer, University of Michigan, on the "Recirculated Oil Gas Process." This process contemplates the manfacture of a straight oil gas in a three-shell carburetted water gas machine, with considerable modification of apparatus and operating principles.

The idea appears to have been born of the erroneous belief that the process recently developed on the Pacific Coast for the manufacture of a high heat value oil gas with a high methane content produces lampblack in the cracking process, whereas the analyses indicate that the Pacific Coast method produces more methane, less hydrogen and less unsaturates than the Recirculated Oil Gas Process, and with no lampblack, even though the cracking be more severe for the production of a lower B.t.u. value.

This process, which is still in the experimental stage, contemplates the use of the tar by-product for heating the checkers and also for conversion to gas. The latter achievement will be particularly meritorious in the promotion of efficient operation, as well as from an engineering standpoint.

This has not yet been attempted in the simplified Pacific Coast process. It adds a complexity to possible emergency operation, which in the general average of oil gas plants does not appear justified at the present time.

We have other reports far too numerous and not of sufficiently great interest to the buk of the industry in the West to discuss here. These deal chiefly with highly carburetted water gas and catalytic methods. All have their merits and are of great interest in their resepective environs.

There is a great forward movement by the industry at present, to solve this highly important problem of a satisfactory substitute for natural gas.

Summary of Research by Willien and White

The following summary of research by L. J. Willien, Gas Engineer, Byllesby Engineering and Management Corp., and C. E. White, Chemist, San Diego Consolidated Gas and Electric Co., both of whom have been instrumental in the evolving of the Pacific Coast method of producing a substitute gas, may be of value to any one contemplating further research or experimentation. It is a partial result of intensive study and laboratory work and is fundamentally applicable in any location, regardless of former methods of gas manufacture.

Large scale experiments made at San Rafael [1] indicated that specific gravity and chemical composition, not the heating value, determined the quality of manufactured gas to substitute for natural gas. Here, oil gas of 1085 B.t.u. and .726 specific gravity burned with a smoky flame in consumers' appliances adjusted to natural gas of 1180 B.t.u. and .65 specific gravity, while oil gas of 975 B.t.u. and .661 specific gravity was a good substitute. It was thought that for equal heating values, oil gas required a higher percentage of primary air to theoretical air than did natural gas for good combustion, because of the large amount of illuminants in

[1] *Western Gas*, August, 1932.
[2] R. B. Harper, Proc. A. G. A., 1931.

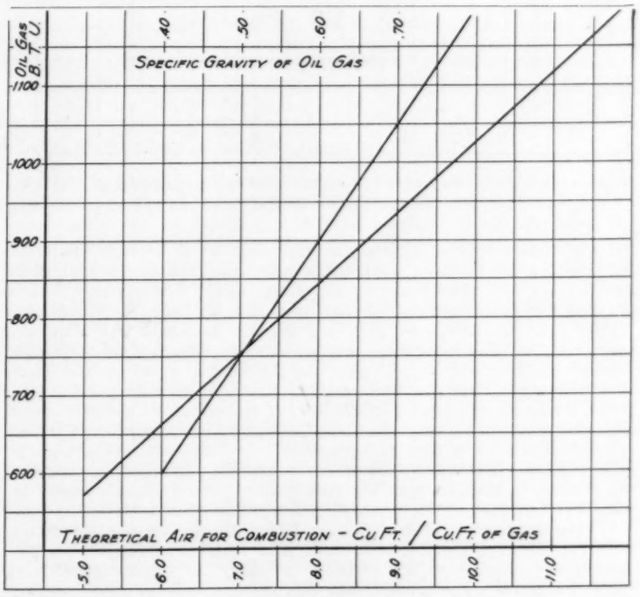


Fig. 1. Oil Gas total air requirement—B.t.u. vs. specific gravity and total air requirement.

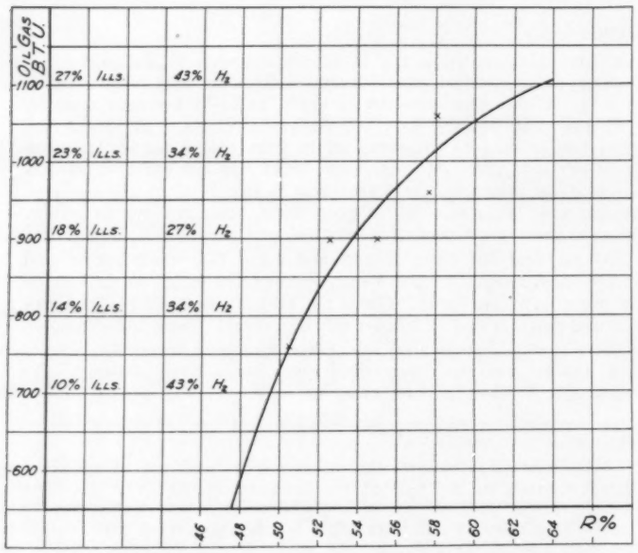


Fig. 2. Oil gas theoretical primary air requirement—B.t.u. vs. R=primary air/total air for good flame.

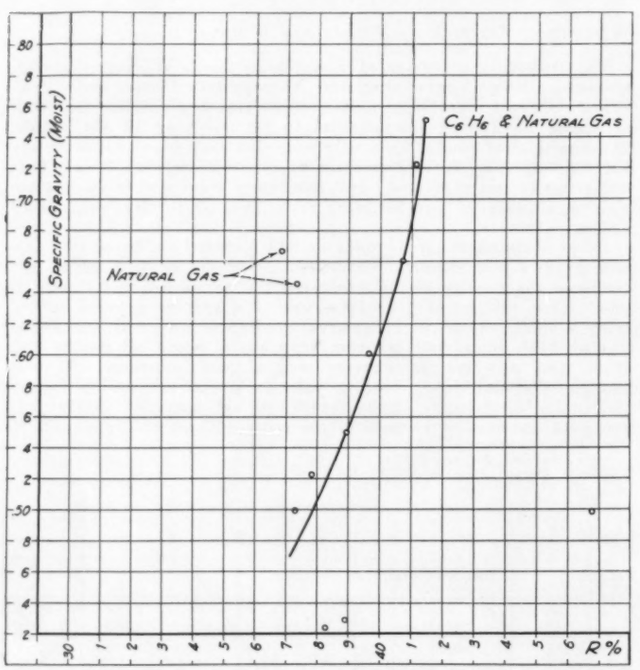


Fig. 3. Experimental primary air requirement—Specific gravity vs. R=primary air/total air for good flame.

oil gas. This seemed logical theoretically: If R denotes the ratio of primary air to theoretical air at any time, and the proper mixture of air and gas should be 175 B.t.u. in the burner head [2] then R may be calculated at 52 per cent for the above natural gas (1180 B.t.u.), and as 61 per cent for the desirable 975 B.t.u. oil gas; i. e., oil gas requires a higher R than natural gas. But the higher the B.t.u. of the oil gas, the higher the gravity; and since the primary air to gas ratio varies with the specific gravity, the 1085 B.t.u. oil gas would under the same conditions show a lower R, viz., 57.9 per cent. But the latter gas for good combustion should require a higher R because of the increased percentage of illuminants. The smoky flame may thus be explained in terms of R: For R to be adequate, the specfic gravity should apparently be the same as that of the natural gas regularly served.

Laboratory experiments in San Diego showed a similar result. Oil gas of varying B.t.u. was made in a small cracking tube. The actual requirement of the ratio R (primary air to theoretical air) was deterdned by test and from the gas analysis for good combustion, observing constant pressure, the burner orifice having been chosen for natural gas; the requirement of R for natural gas was also determined for comparison. The oil gas was about 18 B.t.u. higher than natural gas of same specific gravity. Natural gas, it was found, required a lower R than oil gas of the same specific gravity for a good flame. Benzene added to natural gas raised the value of R. The higher the gravity of the oil gas, the greater was the R requirement for a good flame.

Oil gas of 1077 B.t.u. and .660 specific gravity was a good substitute for natural gas of 1093 B.t.u. and .646 specific gravity without change of pressure, orifice, or air shutter. Oil gas of lower B.t.u. and specific gravity could also be substituted for natural gas, but with a weaker flame. Oil gas of higher specific gravity and B.t.u. than natural gas, however, was not a good stubstitue, burning with a smoky flame. The best substitute for natural gas was that oil gas with specific gravity and B.t.u. nearest that of the natural gas. It appeared that the ratio of primary air entrained to oil gas burned, was a better index to its value as a substitute for natural gas than was R, for the best performing oil gas substitute required the same ratio of primary air to gas as did natural gas. However, natural gas required slightly more total air for combustion than oil gas of the same specific gravity. The experiments also showed that an oil gas with the same ratio R as natural gas is not the best substitute for the latter, although passable; a richer oil gas was preferable to the laboratory. Hence for a well-adjusted flame, the ratio of primary air to gas appears a better guide to the proper oil gas substitute than the ratio of primary air to theoretical air. But the ratio of primary air to gas was found to be a function of the specific gravity; hence oil gas, to serve best as a substitute for natural gas, should have the same specific gravity as the latter. The same was true of the heating value, but apparently in practice the actual heating value of the oil gas may be lower for a given specific gravity than was found in the laboratory.

The laboratory results thus led to the same conclusion reached practically in San Rafael: If oil gas is to be used as a substitute for natural gas, both should have the same specific gravity for the best results. The fundamental requirement seemed to be that both should entrain the same volume of air per cubic foot of gas.

The best oil gas at San Rafael and the laboratory had the following composition:

	San Rafael	San Diego Laboratory
CO_2	1.9 %	0.4 %
Illuminants	20.7 %	22.8 %
O_2	0.2 %	0.4 %
CO	3.2 %	0.4 %
H_2	21.7 %	21.3 %
CH_4	48.0 %	52.6 %
N_2	4.3 %	2.1 %
	100.0 %	100.0 %
B.t.u.	975	1077
Specific Gravity	.661	.660

and was substituted for natural gas with:

	San Rafael	San Diego Laboratory
B.t.u.	1180	1093
Specific Gravity	.65	.646

The San Rafael diesel oil gas here referred to was a product of large scale manufacture in an oil gas generator. The San Diego laboratory gas was made from diesel oil in a cracking tube without the admission of steam or other foreign element. It was a more pure oil gas than obtainable in commercial scale manufacture.

Fig. 1 shows the relation between the B.t.u., specific gravity and total air of the San Rafael oil gas.

Fig. 2 shows the theoretical primary air requirement of the San Rafael gas.

Fig. 3 shows the specific gravity plotted against the experimental ratio of primary air to total air in the San Diego tests.

Fig. 4 shows the specific gravity plotted against the experimental ratio of primary air to gas at San Diego. Why the ratio of primary air to gas is more significant than the ratio of primary air to theoretical air is obvious.

GENERAL

In an oil gas substitute for the slow-burning natural, the quick-burning hydrogen must be maintained at a low percentage to prevent backfiring.

To prevent sooting and smoking the slowburning unsaturates with their high air requirement must also be maintained at a low percentage.

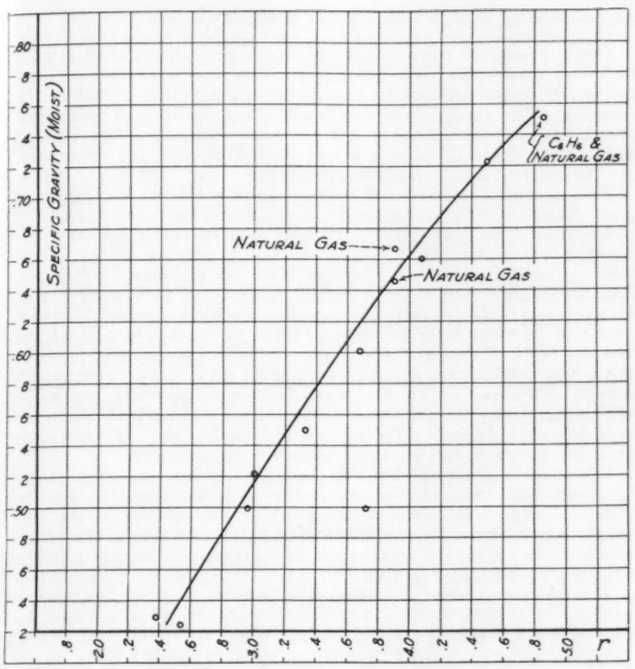


Fig. 4. Experimental primary air requirement—Specific gravity vs. R=primary air/gas for good flame.

In the cracking process low hydrogen results in a high percentage of unsaturates and vice-versa. Consequently a compromise must be drawn between these two opposing conditions, with the result that the gravity of the oil gas cannot be sufficiently lower than that of the natural gas to increase the flow to the burners in proportion to the lowered B.t.u. value of the oil gas. Nor can the B.t.u. of the oil gas be raised to that of the natural gas, due to the inability to properly burn the unsaturates.

Therefore, it necessarily follows that the B.t.u. input to appliances will be decreased with the use of oil gas and the quantity of such gas and the time required for a certain work will be slightly increased.

Although the efficiency of the oil gas is greater than that of natural, there is not sufficient difference to overcome the decreased B.t.u. input. While this might affect various special appliances, it is doubtful if the majority of consumers would note any difference in their service, except through the visible flame characteristics, which, with particular reference to the San Diego tests, were not very pronounced.

It is not believed that a lowering of the heat value of a high B.t.u. gas by approximately 15 per cent, with some increase in efficiency, would be reflected to any appreciable extent in customer billing even over protracted periods of operation.

This being true in the serving of a straight oil gas substitute, it follows that if oil gas be used only to augment the supply of natural, then no loss whatever to the customer could be detected, and no unsatisfactory service conditions would exist.

Chemical Laboratory Methods*

DETERMINATION OF SMALL AMOUNTS OF COMBUSTIBLES IN UNKNOWN GAS SAMPLES BY MEANS OF A MODIFIED HALDANE APPARATUS†

THE Haldane gas analysis apparatus now used by the Los Angeles Gas and Electric Corp. Laboratory (see Fig. 1) for the analysis of gaseous atmospheres, containing small quantities of combustibles, differs considerably from the original type developed by the Bureau of Mines for the analysis of mine air and similar gaseous mixtures.

The major changes, which have been introduced to simplify its maintenance and ease of operation, are confined to the replacement of the original potassium hydroxide and potassium pyrogallate pipettes by the regular Francis Auto bubbling pipettes, such as are used in the Burrell type of gas analysis apparatus. A safety shield of unshatterable glass has been installed for the purpose of rendering protection to the analyst, in case of cracking or explosion in the slow combustion pipette.

The compensating device, which is used for slight changes of temperature and barometric pressure is in the form of an auxiliary tube inclosed in the water jacket with the burette; this was retained and its use made possible by means of a U type manometer (G) and a three-way stop cock (E) at the sampling end of the apparatus.

A strip of flashed opal glass was mounted behind the burette jacket and in the back of the flashed opal glass a 60-watt lamp of cylindrical shape was attached.

This arrangement provided a more even illumination and facilitated the reading of the burette, (F). As seen in Fig. 1, the modified model appears very similar to the large Burrell type of apparatus, in which the fuming sulphuric acid pipette has been eliminated and the general order of the remaining pipettes changed. The elimination of the absorbent pipette for the unsaturated hydrocarbons (SO_3 in Con H_2SO_4) in no way hampered the possibilities of using the modified Haldane as a subsidiary unit to the larger Burrell apparatus. The determinations of the oxygen consumed during the slow combustion process will enable the analyst to estimate the amounts of unsaturated hydrocarbons mathematically, by setting up an additional equation involving the figure of consumed oxygen.

Determination of Combustible Gas

The modified Haldane apparatus is especially adapted for the analysis of gaseous atmospheres containing combustibles in quantities ranging below their explosive limits, with the purpose of identifying the nature of combustibles present.

As an example of its usefulness, we may cite a case in which it is necessary to establish quite definitely the nature of combustibles that were reported present in a sample of manhole atmosphere surveyed by a special crew. The crews are generally equipped with an apparatus capable of indicating the presence of combustibles and their quantities. The nature of combustibles present is necessarily determined in the laboratory. Their determination presents difficulties which increase as the concentration of combustibles decreases and in a great many instances the results obtained by using the larger Burrell apparatus alone, were so uncertain that a measure of doubt always remained, as to their absolute value. The modified Haldane can also be used for the accurate analysis of flue gases, synthetic mixtures of carbon dioxide, natural gas, gasoline vapors, benzene, carbon monoxide, hydrogen, methane, and air mixed in proportion below their lower explosive limits.

Outline of Analytical Procedure

The operation of the apparatus is similar to the operation of the large Burrell and therefore, any gas analyst familiar with the functioning of one type of apparatus can easily work with the other. Of course, to avail oneself to the fullest extent of the precision attainable on the Modified Haldane, one must be more particular in weighing the influencing factors of changing temperatures and barometric pressure while working with the Haldane than one would be when working with the larger Burrell.

The practice has shown that such things as the sensitivity of the "U" type manometer (G) attached to the compensating device are of considerable importance, if data of highest accuracy and consistency are required, and it might even be advantageous to spend more time in investigation of adopting a more sensitive type of manometer in place of the 1 mm. bore "U" type now used with the Haldane. At least two readings five minutes apart should be made prior to entering the final figure for any one determination, in order to assure the equilibrium conditions from volume-temperature standpoint. The temperature of the sample may be too high or too low as compared to the temperature of the graduated burette, immersed in water, and therefore sufficient time should be given for the gas sample to come to the temperature of the burette, in order to get consistency in figures.

A film of water should always be kept in the burette over the mercury, so that any gas drawn into the burette will become saturated with water vapor. Likewise, keep 1 or 2 cc. of water in the compensator tube so that the air in this tube is also saturated. Unless these precautions are taken, the compensating device described will not compensate for change in the vapor tension of water vapor in a gas, due to variations of temperature during analysis. The outline of precautionary measures given above is considered sufficient for any gas analyst to proceed with the modified Haldane and make analysis of gaseous atmospheres, provided of course, they are below the explosive limits.

*Committee Report: Jas. M. North, chairman, L. A. G. and E. Corp.; A. B. Allyne, So. Counties Gas Co.; Mathew Brown, B. C. Electric Railway Co., Ltd.; M. T. Burton, So. Calif. Gas Co.; D. R. Hiskey, So. Calif. Gas Co.; Frederick C. Jones, P. G. and E. Co.; J. T. Roberts, Spokane Gas and Fuel Co.; N. K. Senatoroff, L. A. G. and E. Corp.; S. C. Schwarz, Portland Gas and Coke Co.; C. S. Smith, P. G. and E. Co.; C. E. White, San Diego Consol. G. and E. Co.

†Submitted by M. K. Senatoroff and J. M. North, L. A. G. and E. Corp.

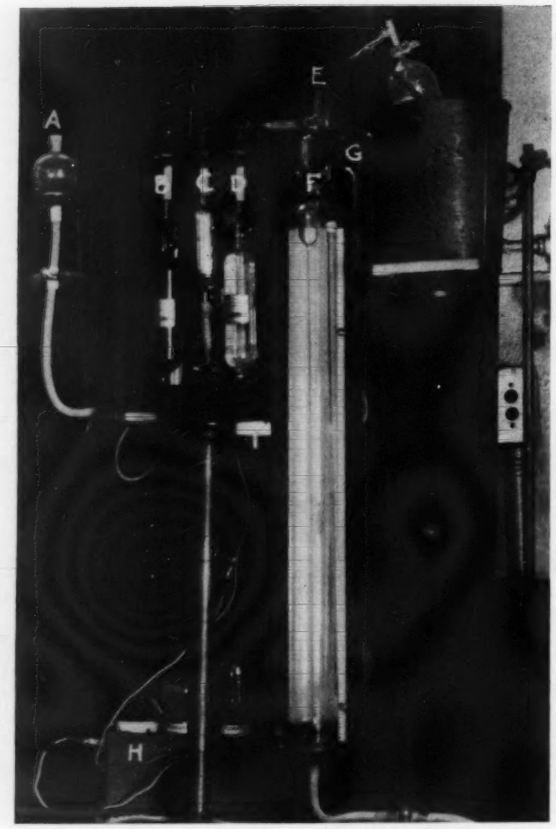


Fig. 1.

Description of Apparatus

A—Leveling bulb, containing pure distilled mercury, and connected with slow combustion pipette (C).

B—Caustic Pyrogallate. Francis bubbling pipette.

C—Slow combustion pipette.

D—Caustic Potash. Francis bubbling pipette.

E—Three-way stop cock at the sampling end of the apparatus, connected with burette (F) and manometer (G).

F—Burette has a total capacity of 21 cc. The bulb at the upper part has a capacity of 15 cc. and is not graduated. The stem has a capacity of 6 cc. and is graduated in hundredths of a cubic centimeter.

G—U-shaped glass manometer of 1 m.m. bore, filled with colored water.

H—Bank of lamps used as a rheostat for heating platinum filament in slow combustion pipette.

For anyone desirous of detailed description of complete procedure and methods of operation of the Haldane apparatus, we recommend Bulletin 197, Department of Commerce, Bureau of Mines, entitled: "Sampling and Examination of Mine Gases and Natural Gas."

Analysis of Synthetic Combustible Gas-Air Mixtures

The relation between the carbon dioxide and the contraction produced by the combustion, indicates the nature of the combustible gas present. When, for instance, the volume of the carbon dioxide is one-half of the volume of contraction, we may correctly assume that the sample contains methane only, provided of course, the sample is composed of one combustible. On the other hand, knowing the composition of the sample, the relationship of carbon dioxide to the contraction may conveniently serve as a means of calibrating the sensitivity of the gas apparatus and the degree of accuracy of the experimental data. With that in view, the writers have prepared five combustible gas-air mixtures and analyzed them with the aid of the modified Haldane apparatus.

Preparation of Gas Mixtures Below Their Explosive Limits

The gas samples were mixed with measured quantities of air, by means of a laboratory wet test meter. The sample of gas, methane for instance, was confined in a calibrated glass pipette of 0.05 cu. ft. capacity. The pipette was connected to the outlet of a gas meter and a large deflated rubber gas bag was attached to the pipette, after which 2.45 cu. ft. of air was passed through the meter into the pipette and thence into the rubber bag.

This proportion of air and methane gave a 2.0 per cent methane gas. Samples were immediately taken from the rubber bag, by passing the gas into glass stoppered pipettes of about 500 c.c. capacity. This was done to stop the loss of gas by means of absorption or diffusion in the rubber bag. In the case of gasoline, benzene and pentane, these being in liquid form, they were placed in a glass stoppered vial, having glass delivery tubes. The vial and sample were weighed and attached to the outlet side of the wet test meter. To the outlet of the vial a connection was made to the top of a miniature gas holder of about 0.15 cu. ft. capacity. A measured amount of air was passed through the meter, so as to obtain a mixture below the explosive limit. The vial was then re-weighed to determine the amount of sample used. Temperature and barometric readings were taken before and after.

While it is realized that, in the case of gasoline, the lighter fractions will evaporate most readily and the resultant gas be richer in lighter constituents rather than representative of the true gasoline composition, we believe that for this very reason the actual mixture we prepared will be more representative of gasoline vapors encountered in practice.

The gas was tested for explosibility prior to removal into a glass pipette for analysis. Due to the extreme volatility of the samples it was difficult to make an exact measurement, and it was not so essential, for our purpose was to see what deviation there would be in the ratio of CO_2 to contraction, rather than the exact per cent of combustibles present in the sample.

The results of analyses are summarized in Table No. 1.

TABLE NO. 1. COMBUSTIBLE GAS-AIR MIXTURES

Nature of Combustible in Air	% Concentr. from Preparation	Average % Concentr. from Analysis	Lower Limit of Inflammability	Average Ratio CO_2/Con'tr.	Theoretical Ratio
Methane	2.0%	1.83%	5.3%	0.5020	0.5000
Natural Gas	2.0	1.89	4.8	0.6145	0.5598*
Pentane	1.5	1.77	1.5	1.1814	1.2500
Gasoline	1.5	0.71	1.55	1.3484	1.3694†
Benzene	0.5	0.29	1.5	2.5660	2.4000

*Actual composition of the natural gas on that day was taken as 16.5% C_2H_6, 82.9% CH_4 and 0.60% N_2.

†A hypothetical composition for the gasoline was taken as 75% octane and 25% nonane.

Data given above represent the averages of several determinations of a combustible in a given synthetic mixture.

To give some idea of the deviations from the averages of the actual experimental figures, the latter are given in Tables No.'s 2, 3, 4, 5 and 6.

TABLE NO. 2. ANALYSIS OF METHANE MIXTURE

Percentage of Methane Prepared = 2.0%
Formula for Calculation CH_4 = CO_2 formed

Test No.	Total CO_2	Total Contraction	Ratio CO_2/Contr.	% CH_4 from Analysis
1.	0.375 cc.	0.747 cc.	0.5020	1.79
2.	0.391 cc.	0.779 cc.	0.5019	1.86

TABLE NO. 3. ANALYSIS MADE ON NATURAL GAS MIXTURE

Percentage of Natural Gas Prepared = 2.0%
Formula for Calculation: $C_2H_6 = \frac{2}{3}$ (2 CO_2 − Contraction)
$CH_4 = CO_2 - 2\ C_2H_6$

Test No.	Total CO_2	Total Contraction	Ratio CO_2/Contr.	% Nat. Gas from Analysis
1.	0.495 cc.	0.874 cc.	0.566	1.99
2.	0.545 cc.	0.840 cc.	0.649	1.80
3.	0.543 cc.	0.807 cc.	0.673	1.69
4.	0.499 cc.	0.876 cc.	0.570	1.99

TABLE NO. 4. ANALYSIS OF PENTANE MIXTURE

Percentage of Pentane prepared = 1.5%
Formula for Calculation: $C_5H_{12} = 1/5\ CO_2$

Test No.	Total CO_2	Total Contraction	Ratio CO_2/Contr.	% C_5H_{12} from Analysis
1.	2.285 cc.	1.931 cc.	1.183	2.18
2.	1.659 cc.	1.396 cc.	1.188	1.58
3.	1.644 cc.	1.402 cc.	1.173	1.57

TABLE NO. 5. ANALYSIS OF GASOLINE MIXTURE

Percentage of Gasoline prepared = 1.5%
Formula for Calculation: This mixture was considered as 75% Octane and 25% Nonane.
Octane $C_8H_{18} = CO_2$ formed
Nonane $C_9H_{20} = CO_2$ formed

Test No.	Total CO_2	Total Contraction	Ratio CO_2/Contr.	% Gasoline from Analysis
1.	1.241 cc.	0.919 cc.	1.350	0.73
2.	1.140 cc.	0.830 cc.	1.374	0.66
3.	1.287 cc.	0.974 cc.	1.321	0.74

TABLE NO. 6. ANALYSIS OF BENZENE MIXTURE

Percentage of Benzene prepared = 0.5%
Formula for Calculation: $C_6H_6 = 1/6\ CO_2$ formed

Test. No.	Total CO_2	Total Contraction	Ratio CO_2/Contr.	% C_6H_6 from Analysis*
1.	0.506 cc.	0.194 cc.	2.608	0.40
2.	0.412 cc.	0.139 cc.	2.964	0.33
3.	0.187 cc.	0.088 cc.	2.125	0.15

* These samples gave indications of progressive condensation, perhaps due to temperature fluctuations between time of sampling and analysis.

Discussion of Results

One very important fact that has been established by these analyses is that the experimental data are of semi-quantitative nature and, therefore, very important for the investigations of explosive air mixtures. We named them semi-quantitative, at least for the present, because the CO_2/contraction experimental ratio is not, in all cases of analyzed mixtures, equal to the theoretical ratio. The explanation may be found with equal degree of fairness either in the lack of the sensitivity of the apparatus or in the uncertainty of the exact chemical composition of the combustible constituent as in the case of natural gas and gasoline air mixtures.

Only extensive work with the apparatus will reveal the outweighing influence of either of the two mentioned factors; for the present, however, it will suffice to say that as a supplementary apparatus to the larger Burrell, it is indispensable, and the results, considering the range of concentration of combustibles in the sample, are more than satisfactory.

Examples of Calculations for Determining Combustibles in Air-Gas Mixtures

A. Mixture containing Hydrogen, Methane and Carbon Monoxide:

1. $2H_2 + O_2 = 2H_2O$ ..... CONTRACTION = $3/2\ H_2$; ..... $CO_2 = 0.0$;
2. $CH_4 + 2O_2 = CO_2 + 2H_2O$ .... " = $2\ CH_4$; .... " = CH_4;
3. $2CO + O_2 = 2CO_2$ ..... " = $1/2\ CO$; .... " = CO;

The following relations are obtained from equations 1, 2 and 3:

4. $3/2\ H_2 + 2CH_4 + 1/2\ CO$ = CONTRACTION
5. $CH_4 + CO = CO_2$
6. $1/2\ H_2 + 2CH_4 + 1/2\ CO$ = OXYGEN CONSUMED

Solving equations 4 and 6 simultaneously, we obtain formula for H_2 = Contraction − Oxygen Consumed
Likewise from equations 4 and 5, we derive formula for

$$CH_4 = \frac{2\ \text{Contraction} - CO_2}{3} - H_2$$

Equation 5 gives us formula for $CO = CO_2 - CH_4$

B. Mixture containing Methane and Ethane:

1. $CH_4 + 2O_2 = CO_2 + 2H_2O$ .. CONTRACTION = $2CH_4$ .. $CO_2 = CH_4$,
2. $C_2H_6 + 3\frac{1}{2}O_2 = 2CO_2 + 3H_2O$ .... " = $2\frac{1}{2}C_2H_6$ " = $2C_2H_6$

From equations 1 and 2 the following relations are obtained:

3. $2CH_4 + 2\frac{1}{2}C_2H_6$ = CONTRACTION
4. $CH_4 + 2\ C_2H_6 = CO_2$

Solving equations 3 and 4 we obtain formula for $C_2H_6 = \frac{2}{3}$ (2 CO_2 − Contraction)
From equation 4 we derive $CH_4 = CO_2 - 2\ C_2H_6$

C. Mixture containing Methane, Ethane and Benzene:

1. $CH_4 + 2O_2 = CO_2 + 2H_2O$ ..... CONTRACTION = $2CH_4$ .. $CO_2 = CH_4$;
2. $C_2H_6 + 3\frac{1}{2}O_2 = 2CO_2 + 3H_2O$ .... " = $2\frac{1}{2}C_2H_6$ .. " = $2C_2H_6$;
3. $C_6H_6 + 7\frac{1}{2}O_2 = 6CO_2 + 3H_2O$ .... " = $2\frac{1}{2}C_6H_6$ .. " = $6C_6H_6$;

From equations 1, 2 and 3 the following relationship is established:

4. $2CH_4 + 2\frac{1}{2}C_2H_6 + 2\frac{1}{2}C_6H_6$ = CONTRACTION
5. $CH_4 + 2\ C_2H_6 + 6\ C_6H_6 = CO_2$
6. $2CH_4 + 3\frac{1}{2}C_2H_6 + 7\frac{1}{2}C_6H_6$ = OXYGEN CONSUMED

Subtracting equation 4 from equation 6, we obtain:

7. $C_2H_6 + 5\ C_6H_6$ = OXYGEN CONSUMED − CONTRACTION

Simultaneous solution of equations 5 and 6, likewise gives us equation 8:

8. $\frac{1}{2}\ C_2H_6 + 4\frac{1}{2}\ C_6H_6 = 2\ CO_2$ − OXYGEN CONSUMED

From equations 7 and 8, we get the formula for determination of C_6H_6, as follows:

9. $C_6H_6 = CO_2 + \frac{1}{4}$ (CONTRACTION − 3 OXYGEN CONSUMED)

From 7, we obtain the formula for Ethane:

10. C_2H_6 = OXYGEN CONSUMED − CONTRACTION − $5\ C_6H_6$.

Equations 4 and 6 solved simultaneously give us the formula for Methane:

11. $CH_4 = \frac{1}{4}$ (3 CONTRACTION − OXYGEN CONSUMED) − C_2H_6

Conclusions

The modified Haldane, like the original apparatus, has some advantages and disadvantages. Some of them are common to the old type of apparatus; others were acquired during the process of modification.

Limitations:

1. The composition of the sample to be analyzed should be known to the analyst, at least to the extent of its explosive hazard. Only the mixtures containing combustibles in percentages below the explosive limit could be handled with safety in the apparatus.

2. The sample must contain enough oxygen to burn the combustibles completely, because the construction of the burette (F) is such that premixing of the sample with oxygen in the apparatus itself is impossible.

Note: If necessary, these two limitations could be overcome by premixing with air or oxygen prior to analysis.

Advantages:

1. The replacement of the original caustic potash and potassium pyrogallate pipettes, by the Frances Auto bubbling pipettes resulted in the elimination of the rubber tubing connection filled with caustic solutions, which constituted the most objectionable feature of the old Haldane from the standpoint of the maintenance requirements.

2. The replacement of the above pipettes resulted in the increased volumes of absorbent solution and in turn increased their useful life between rechargings.

3. In conjunction with the electric gas leak indicating devices, now on the market and with the large Burrell apparatus on hand in most of the laboratories, the modified type of Haldane permits analysis of almost any gas mixture that requires accuracy and precision above that which is obtainable on the larger Burrell.

"Per cent of Explosibility" obtained from the reading of the scale on a gas leak indicator, will serve as a guide in determining the type of apparatus to use in analyzing the unknown gaseous sample.

TESTS FOR RUBBER GASKET MATERIALS*

This problem was undertaken to develop a standard procedure that would be representative enough to get a comparison between different procedures for testing rubber materials. As the problem stands now, there is not a general satisfactory method available; each laboratory tests them in its own way and the data are neither comparable or absolute in their values.

For this purpose, questionnaires were sent out to the members, asking them to state their methods of testing. The answers received seemed to indicate the need for a more reliable test. In none of the tests has it been attempted to reproduce the condition of the gasket under compression, as all the tests so far reported consist in the immersion of the uncompressed rubber in various solvents. The writer considers the subject important enough to recommend a continuance for the next year's Chemical Methods Committee.

REAGENTS FOR GAS ANALYSIS*

Several new reagents for gas analysis have been on the market, but there does not seem to be enough information obtainable from the users so it was decided to have this committee investigate the merits of these purchased reagents with the ones prepared in the laboratory. The problem of reagents for gas analysis was started by sending out questionnaires to the members. The answers received were compared and found to be contradictory in several instances. For example: In some cases the patented reagents seemed to justify their price, whereas in others the laboratory preparations were considered just as satisfactory. It is, therefore, desirable to have this problem continued on the next year's Chemical Laboratory Methods Committee. A few of the purchased reagents to be considered are the following:

Oxsorbent for oxygen absorption, and Cosorbent for carbon monoxide absorption, both obtainable from the Burrell Technical Supply Co., 1942 5th Avenue, Pittsburgh, Pa.

Seez O_2, an oxygen absorbent, sold by The Hays Corp., Michigan City, Ind.

*Submitted by J. M. North, Los Angeles Gas and Electric Corp.

Gas Holder Maintenance†

THE USE OF NON-DRYING OILS, AND PAINTS, FOR THE PROTECTION OF GAS STORAGE HOLDERS

THE gas storage holder has come to play a very important part in the modern gas producing and distributing system. It acts as a balancing medium between the source of production and the countless channels of widely fluctuating demands of consumers. The gas holder, from its very nature, must be large and to the ordinary layman a cumbersome appearing mass of steel.

The fact that the holder is entirely built of metal and that it is in contact with gas, oxygen and water tends to promote corrosion possibilities and likewise, due to its mass, it also may often have a tendency to present an unsightly appearance.

It is the purpose of this article to dwell on the sources and prevention of corrosion and also on the protection of the holder by means of the proper application of paints and non-drying oils.

Thos. N. Kellett
Chairman

I. Causes for Gas Holder Corrosion.

Holder corrosion due to the action of water, oxygen and carbon dioxide on metal is the source of a great deal of annoyance and expense.

When iron and water are in contact a chemical reaction takes place forming iron hydroxide and hydrogen, which are slightly soluble in water. The presence of oxygen in water causes a reaction between the iron hydroxide to form the insoluble or more stable ferric hydroxide.

When the lifts are lowered into the pit water, several things happen which affect these chemical reactions—oxygen is carried into the water, the hydrogen film may be disturbed, the water in the immediate vicinity of the iron is mixed up so as to bring new water unsaturated with the soluble iron hydroxide in contact with the iron, and the precipitated insoluble iron hydroxide is stirred up. When the lifts are raised a certain amount of water saturated with ferrous hydroxide clings to the sheets. The ferrous hydroxide reacts with the water from the pit and oxygen from the air, to form ferric hydroxide.

The lifts will then be streaked with rust and be unsightly, even though they may be perfectly protected by a good coat of paint.

Many attempts have been made to prevent this precipitation of iron hydroxide. It is possible to partially accomplish this result through the use of chemicals. However, this treatment is so costly that for practical purposes it must be set aside as impractical.

II. The Use of Paints for Holder Protection

In order to preserve the holder structure against corrosion, it has been common practice for many years to use various forms of paints applied on the surface of the cleaned metal. By various color combinations it has likewise been possible to have the holders present a good appearance and thereby conceal a large part of their unsightly massiveness.

Many different kinds of primers and finish coats have been developed in the paint line, many of which have rendered satisfactory service. It is not the purpose of this article to enter into the discussion of the relative merits of the various paint products on the market.

Until recent years it has been the policy of nearly all gas utilities to protect the entire outer surface of their holders with some form of paint.

The practice of the Los Angeles Gas and Electric Corp. in regards to paint application on a new holder has been to apply first, a thin coat of red or white lead. This material is allowed to dry thoroughly. A second coat of red or white lead is then applied; the consistency of this coat is somewhat heavier than the first application. After thoroughly drying out the surface is then ready for the final or finish coat.

A green graphite paint was used for many years, with very good lasting qualities. During the past few years, however, the company has been using aluminum paint on all the crowns, framework and stairs. On the holder pit, however, green graphite is still being used.

The company's experience has been that the above applications render a good protection and likewise present an attractive appearance. For many years the lifts of the holders were painted in the same manner—that is two coats of primer and one coat of green graphite paint for a finish coat. While this rendered a good protection for the metal, it was found that the constant cupping and uncupping of the various holder lifts, due to the water in the pit, caused a film to be formed over the paint on the various lifts. While the paint itself was not injured to any great extent, nevertheless it presented an unsightly appearance.

For this reason and also for the fact that the cups of the holders and dam sheets were subject to corrosion, it was deemed advisable to experiment with various forms of oil as a protection for the lifts and cups.

III. Bituminous Materials as a Protection Against Corrosion

The use of non-drying oils for the protection of the lifts and cups of gas storage holders has been rapidly gaining favor among gas utilities during the past few years.

The added protection to the cups and dam sheets as well as the lifts themselves, and the better holder appearance secured by the use of non-drying oils, have been important factors in this rapid changeover.

The first use of bituminous oil in a water sealed holder, to come to the committee's knowledge, occurred in 1905; no doubt in some cases the practice dates back very much farther than that.

It has only been during the last 15 years, however, that the gas industry, realizing the extent to which corrosion was going on in the various large storage holders, deemed it necessary to investigate the possibility of using products other than paints for protection against corrosion.

Various forms of oils and tar products have been used during the past few years, with apparent success. In 1922, various concerns appreciating the business opportunities existing, started the manufacture of various non-drying oils for use on lifts and cups of water-sealed storage holders.

At the present time there are four major products in use for holder protection: Imunol, Calol Gas Holder Oil No. 2, No-Ox-id Holder Seal, and compounded fuel oils and lubricating oils.

All of these products have been in use for some time and all seem to give satisfactory service. Many instances could be stated where the use of non-drying oils has greatly reduced the corrosion and likewise improved the outward appearance of the structures.

†Committee Report: Thos. N. Kellett, chairman, L. A. G. and E. Corp.; C. W. Beck, L. A. G. and E. Corp.; W. E. Bradford, Northwest Cities Gas Co.; M. J Cereghino, L. A. G. and E. Corp.; Walter H. Cohick, P. G. and E. Co.; G. F. Cruickshank, So. Counties Gas Co.; J. A. Harritt, San Diego Consolidated G. and E. Co.; F. C. Hawks, Wash. G. and E. Co.; John Keillor, B. C. Elec. Power & Gas Co.; Don Murphy, So. Calif. Gas Co.; H. M. Thomas, Northwest Cities Gas Co.; O. L. Wrestler, L. A. G. and E. Corp.

An interesting experience in connection with two 1-million cubic foot capacity holders of the Los Angeles Gas and Electric Corp. clearly demonstrates the results of the use of holder oil as a protecting medium against corrosion.

Some years ago these holders were dismantled and moved to a new location in Pasadena and rebuilt. Within six years of this rebuilding, it was found that all the cups and dam sheets had to be replaced, which necessitated the bottoming of the holders, purging and necessary repairs, at a cost of several thousand dollars. After the holders were properly repaired and inflated a non-drying oil was applied. These holders have since been in service some eight years, with no pitting or rusting whatsoever to the lifts, cups or dam sheets.

Since the first application of an oil or tar product for holder protection, numerous mixtures of oil, tar and carbon have been compounded in an effort to find the most suitable product that could be developed.

It has been definitely proven, through years of experience of the Los Angeles Gas and Electric Corp., that as far as protection from rusting and pitting is concerned, any neutral oil low in sulphur content gives satisfactory results.

However, as far as film texture and appearance is concerned, a great deal of research work can be done to determine what compounded product will render the most satisfactory service for the money invested.

In choosing a non-drying oil for use on the lifts of a water-sealed holder, which will maintain a good black color over a period of one or two years, one must be careful to select an oil that will not be affected by sun rays or that will not easily be washed off by rain water.

IV. Review of Questionnaire on the Use of Non-Drying Oils for Holder Protection

The consensus of opinion of the several gas utilities which responded to the questionnaire sent out on the use of non-drying oils for holder protection seems to be that the practice is an improvement over the former painting methods.

The holder lifts are better protected against corrosion and likewise present a better appearance. A number of different products seem to have been tried out, with varying degrees of success.

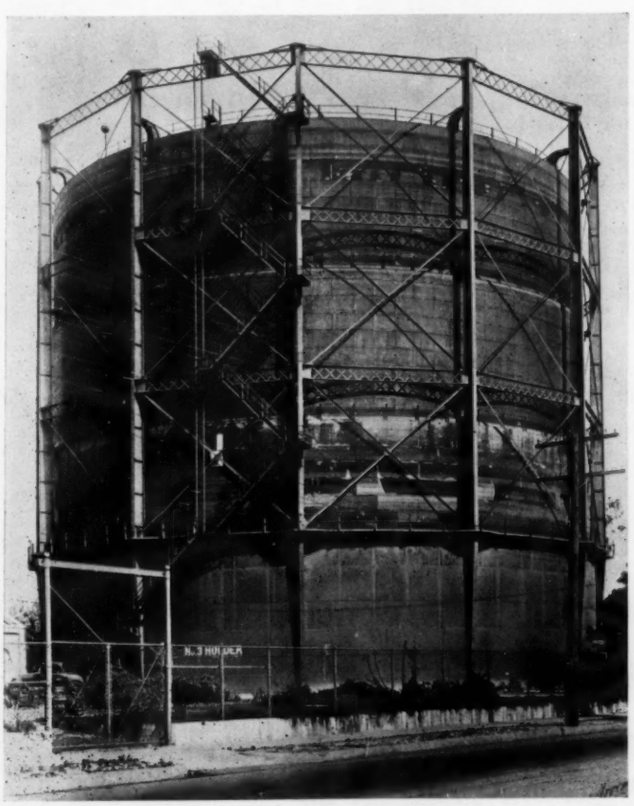


Fig. 1. Showing a 1-million cu. ft. holder of the Los Angeles Gas and Electric Corp. located at Pasadena. This has had no oil treatment of any sort, and plainly shows the deposition of iron oxide on top of the painted lifts. This holder presents a very unsightly appearance and likewise leaves the cups and dam sheets open to corrosion.

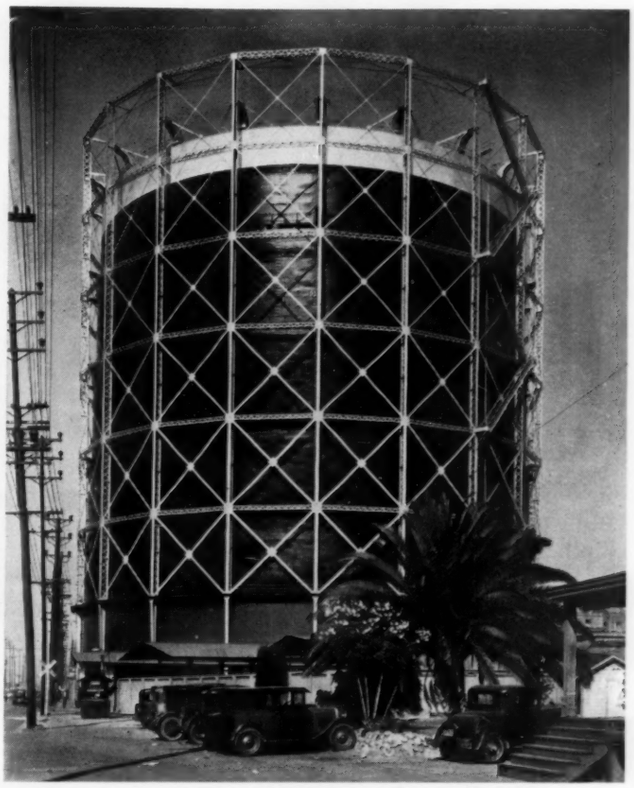


Fig. 2. Showing the 5-million cu. ft. holder of the Los Angeles Gas and Electric Corp. located at 7th and Alameda Streets in Los Angeles. This holder is treated with a non-drying oil. This treatment has shown excellent results both as to appearance and protection.

It appears as though protection is obtained with the use of almost any oil product, but that the blackish appearance varies a great deal, depending upon the material used.

One company using a specially prepared mineral oil product reports a good appearance, with non-drying qualities, after 40 months of service.

The best period of the year to coat the lifts seems to be in the summer time, when the rains are at a minimum. This allows the coating to adhere better to the lifts and when the rainy season approaches, the coating has a much better opportunity of clinging to the holder lifts.

Some of the essential features to consider, in order to obtain satisfactory results in the application of oil coatings, are:

(1) All lifts should be provided with dam sheets of sufficient height to prevent the holder from overflowing during heavy rains.

(2) Install baffles in the cups or pit to prevent excessive loss of oil due to severe winds.

(3) Apply original oil coating, either on cleaned metal or painted surface.

(4) Apply oil coating during summer season, in order to allow coating to become tacky before rainy season sets in.

(5) Use a non-drying oil that has as many of the following characteristics as possible:

(a) Non-drying
(b) Black in color
(c) Good hiding power
(d) Non-checking
(e) Non-peeling
(f) Smooth in appearance on application
(g) Resistant to rain and wind
(h) Will maintain a black color and not turn brown or variegated
(i) Constant specific gravity less than water
(j) Non-emulsifying with water
(k) Non-setting in storage
(l) Rust preventive

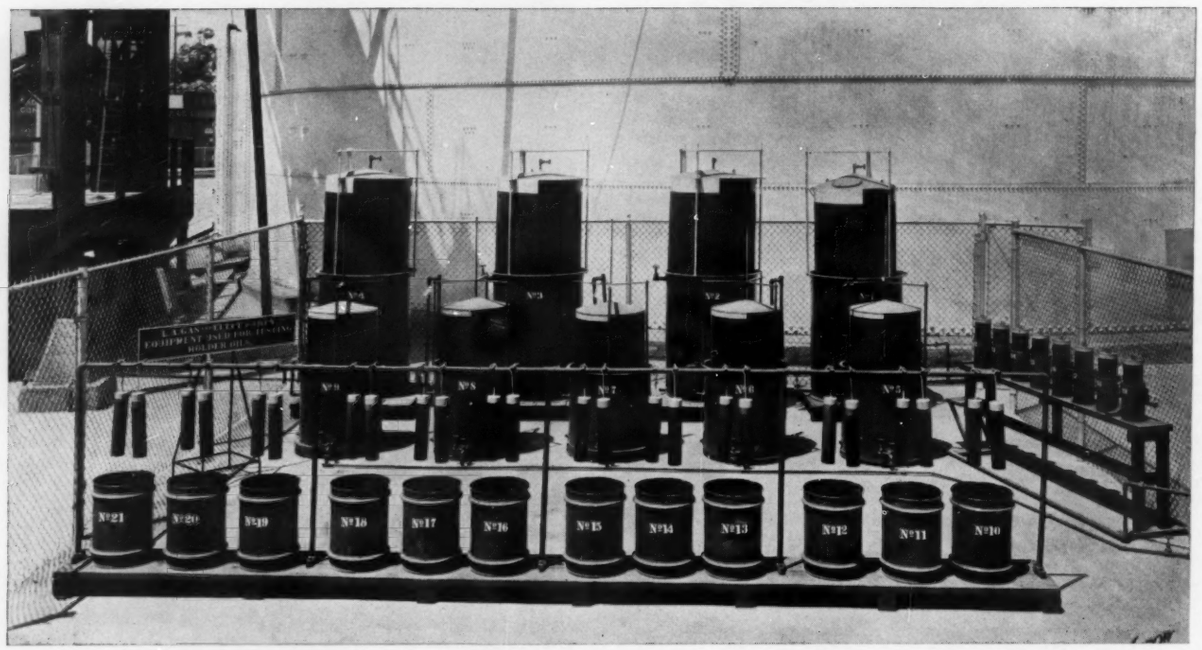


Fig. 3. Showing a view of the equipment used for testing holder oils at the gas works of Los Angeles Gas and Electric Corp.

(m) Constant viscosity
(n) High flash point
(o) High fire point

V. Oil Coating of Lifts versus Painting

Considerable work has been done by the Los Angeles Gas and Electric Corp. in the development of holder oils, and in an attempt to study the relative merits of oil coating of the lifts of water-sealed holders in comparison with the older method of painting of the same structures. Table No. 1 gives data gathered over a five years' period, on a 1-million, 5-million and 10-million cu. ft. holder, using a non-drying oil in comparison with red lead primer and green graphite paints.

TABLE NO. 1. COMPARATIVE COST OF OIL COATING LIFTS VERSUS PAINTING

1-Million cu. ft. Holder—"Oil"

	1st Year	2nd Year	3rd Year	4th Year	5th Year
1st Lift (gal.)	150	100	100	100	100
2nd Lift (gal.)	150	100	100	100	100
3rd Lift (gal.)	350	150	100	100	100
Sub-Total (gal.)	650	350	300	300	300

Grand Total, 1,900 gal. oil $446.50
Labor—1½ Man Days per dip at $6.00 per Man Day 45.00

Grand Total Cost $491.50

1-Million cu. ft. Holder—"Paint"
(Based on 5-Year Period)

1st Lift
20 gal. primer at $2.10 per gal. ..... $ 42.00
17 gal. finish coat at 2.00 per gal. 34.00
23 man days at $6.00 ..... 138.00

2nd Lift
33 gal. primer at 2.10 per gal. 69.00
28 gal. finish coat at 2.00 per gal. 56.00
38 man days at $6.00 ..... 228.00

3rd Lift
33 gal. primer at 2.10 per gal. 69.30
28 gal. finish coat at 2.00 per gal. 56.00
38 man days at $6.00 ..... 228.00

Grand Total $920.60

5-Million cu. ft. Holder—"Oil"

	1st Year	2nd Year	3rd Year	4th Year	5th Year
1st Lift	350	200	200	200	200
2nd Lift	350	200	200	200	200
3rd Lift	350	200	200	200	200
4th Lift	350	200	200	200	200
5th Lift	700	350	200	200	200
	2,100	1,150	1,000	1,000	1,000

Total Oil, 6,250 gal. $1,468.75
Labor, 3 man-days per dip at $6.00 per man-day 90.00

Grand Total $1,558.75

5-Million cu. ft. Holder—"Paint"
(Based on 5-Year Period)

1st Lift
38 gal. primer at $2.10 per gal. ..... $ 79.80
32 gal. finish coat at 2.00 per gal. 64.00
45 man days at $6.00 ..... 270.00

2nd Lift
47 gal. primer at 2.10 per gal. 98.70
40 gal. finish coat at 2.00 per gal. 80.00
56 man days at $6.00 ..... 336.00

3rd Lift
63 gal. primer at 2.10 per gal. 132.30
53 gal. finish coat at 2.00 per gal. 106.00
75 man days at $6.00 ..... 450.00

4th Lift
63 gal. primer at 2.10 per gal. 132.30
53 gal. finish coat at 2.00 per gal. 106.00
75 man days at $6.00 ..... 450.00

5th Lift
63 gal. primer at 2.10 per gal. 132.30
53 gal. finish coat at 2.00 per gal. 106.00
75 man days at $6.00 ..... 450.00

Grand Total $2,993.40

10-Million cu. ft. Holder—"Oil"

	1st Year	2nd Year	3rd Year	4th Year	5th Year
1st Lift	500	250	250	250	250
2nd Lift	500	250	250	250	250
3rd Lift	500	250	250	250	250
4th Lift	500	250	250	250	250
5th Lift	1,000	500	250	250	250
Total	3.000	1,500	1,250	1,250	1,250

Total, 8,250 gal. Oil $1,938.75
Labor, 3 man-days per dip at $6.00 per man-day 90.00
Grand Total $2,028.75

10-Million cu. ft. Holder—"Paint"
(Based on 5-Year Period)

1st Lift		
53 gal. primer at	$2.10 per gal.	$ 111.30
45 gal. finish coat at	2.00 per gal.	90.00
63 man days at	$6.00	378.00
2nd Lift		
66 gal. primer at	2.10 per gal.	138.60
56 gal. finish coat at	2.00 per gal.	112.00
79 man days at	$6.00	474.00
3rd Lift		
88 gal. primer at	2.10 per gal.	184.80
75 gal. finish coat at	2.00 per gal.	150.00
105 man days at	$6.00	630.00
4th Lift		
88 gal. primer at	2.10 per gal.	184.80
75 gal. finish coat at	2.00 per gal.	150.00
105 man days at	$6.00	630.00
5th Lift		
88 gal. primer at	2.10 per gal.	184.80
75 gal. finish coat at	2.00 per gal.	150.00
105 man days at	$6.00	630.00
Grand Total		$4,198.30

Comparative results between oil coating lifts and painting over a 5-year period show a saving of about half in favor of oil coating. In addition, a better appearing holder is presented and likewise the holder is subject to less corrosion.

CODE OF FAIR COMPETITION FOR THE NATURAL GAS INDUSTRY

(Continued from Page 22)

In order to keep the President of the United States and the Administrator informed as to the observance or non-observance of this Code, each employer shall prepare and file with the statistical department of the Natural Gas Division of the American Gas Association at such times and in such manner as may be prescribed, statistics covering the number of persons employed, wage rates, earnings, hours of work and such other data or information as the Recovery Executive Committee may from time to time require.

Any employer may participate in this code and in any revisions or additions thereto by accepting the proper pro rata share of the cost and responsibility of creating and administering it, either by becoming a member of the Natural Gas Division of the American Gas Association or by paying an equitable proportion of the administration cost.

V. AMENDMENTS

Such of the provisions of this code as are not required to be included therein by the National Industrial Recovery Act, may, with the approval of the President, be modified or eliminated as changes and circumstances or experience may indicate.

This code shall become effective ten days after date of approval.

Dated: August 11, 1933.

NATURAL GAS DIVISION,
AMERICAN GAS ASSOCIATION
By R. W. Gallagher,
420 Lexington Ave., New York, N. Y.

Previewing the 40th P. C. G. A. Annual Convention

(Continued from Page 24)

chairman of the Public Relations Section's committee on Legislation and Taxation, will be the speaker of the evening. If you have heard Edwards—and then add this theme—you won't miss the annual banquet. Announcement of the Awards Committee's findings will be made, and the ceremonials incidental to the transfer of responsibility from one administration to its successor will be observed. There will be appropriate entertainment, and the annual ball will coincide with the closing of the final convention day.

SATURDAY, SEPTEMBER 16

Forenoon: Post-Convention Golf Tournament. This happy event will be under the capable direction of A. L. Spring, chairman of the Sports Committee. Golfers should arrange their schedules to enter the lists with Art and his co-planners. Play will be at Brentwood Country Club, beginning at 8:30 a.m., and the fee is $1. The Brentwood course will be open to registered delegates on Thursday and Friday preceding the tournament for the same modest greens fee.

CONVENTION EXHIBITS

The Advertising Section's Exhibit Committee, under chairmanship of Al. C. Joy, is arranging the annual exhibit of gas company advertising. This bids fair to be of exceptional interest, and delegates to the convention are advised to come with the purpose of examining this display. First and second prizes are offered.

The annual exhibit of Women's Committee accomplishment also is being prepared by the chairman, Mrs. Rees. This will be of special interest to general, commercial, personnel and public relations executives.

LATCH STRING PROTRUDES

All gas industry folk will find the latch string on the outside of the door at the Ambassador, Los Angeles. There will be no registration fee. The Ambassador's regular program of entertainment and recreation will, of course, be available to those in attendance, so that, after all, the facilities for amusement will be greater than the foregoing sketch would indicate.

International Outlook for A. G. A. Meeting

(Continued from Page 23)

Publicity and Advertising Section: Jay Barnes, New Orleans Public Service Inc., chairman.

"Publicity and Industry in Great Britain" is the subject assigned to R. P. Ryan of the Gas Light & Coke Co., London; George W. Allen, secretary-treasurer of the Canadian Gas Association, will also bring a message on "Pitfalls of Advertising and Advertising Men." The advertising-publicity group will also hear C. N. Lauer, chairman of the National Directing Committee of Executives on the A.G.A. advertising-merchandising program, as well as other notable speakers.

Technical Section: J. A. Perry, The United Gas Improvement Co., chairman.

Technical meetings will be at the Blackstone Hotel. F. M. Birks of the Gas Light & Coke Co., London, will tell the delegates how coke is prepared for the London market; reports will be offered by the section's chemical, distribution and production committees; there will be a symposium on purification, and papers on non-stop pilot control, the gum problem, gas and coke-making qualities of American coals.

MEASUREMENT and CONTROL

READING DISC

Showing the "spread" of the lines of the "family of reading curves." The same reading disc is used in all spiragraphs for Westcott charts, regardless of differential or static pressure ranges, and regardless of whether the chart is of the new L-10 variety or not. Reading discs for Foxboro or other charts are necessarily different, as the inner and outer diameters of such charts are different.

The Spiragraph: A New Method for Calculating Orifice Meter Charts

By Wm. C. Poe

*Los Angeles Gas and Electric Corporation**

SYNOPSIS: A new method for calculating orifice meter charts has been developed by the Los Angeles Gas and Electric Corp. and is used by them on charts that require precise hourly calculation. It comprises two transparent celluloid discs, the diameter of the chart, and is called a Spiragraph because it solves the equation, $Q=C \times \sqrt{hp}$, by a graphic method using spirals. With its use the differential pen line of the chart is read directly in cubic feet of gas. The static pressure line is not read. It is mathematically exact in principle. Its operation is very simple. Tests have shown it more reliable than other methods due to less opportunity for human error. Spiragraphs may be borrowed for experimental purposes by gas corporations. They are not for sale.—*Author.*

IT IS the purpose of this paper to discuss an improvement in the art of reading and calculating circular orifice meter charts, which involves the use of a new and astonishingly simple device. This device, composed of two transparent celluloid discs, makes the differential pen line of a chart directly readable in cubic feet of gas, instead of in the "inches of water" in which it was recorded. Thus one reading serves for two (as the static pressure line need not be read), and the multiplying that is required by the customary method is entirely eliminated.

Wm. C. Poe

At first thought it would seem an impossibility that the differential line of the chart could be read as cubic feet, because the cubic foot flow is controlled by many other things beside the differential, namely, the static pressure, the temperature, the specific gravity and the diameters of the orifice and tube, none of which is taken into account by that part of the recording mechanism which traces the differential record on the chart.

However, the Los Angeles Gas and Electric Corp. has developed for its own convenience in reading hundreds of charts, a device known as a "Spiragraph" which functions with the effect described. A number of "Spiragraphs" are in dajly use, showing a saving of about two-thirds of the time usually required for chart calculation, and a careful check of the accuracy of their results proves them to be equally accurate to those obtained by the conventional extension book and calculation sheet method when at its best.

The name "Spiragraph" is derived from the fact that, by means of a family of 208 *spiral* curves (that are printed on an upper 10-inch, circular transparent disc), together with a single spiral curve (printed on a similar lower disc), the device gives what is substantially a *graphic* method of chart calculation as contrasted with the conventional mathematical or extension book method.

Although the differential pen record of the chart is not a record of gas flow, because it lacks consideration of other equally important data, yet, with the spiragraph in place, the missing data are included. The combination of the spiragraph with the chart brings about the necessary conditions under which the differential line, (by referring its height to the family of numbered spirals of the spiragraph disc, instead of to the family of numbered circles on the chart), may be read, as stated, in cubic feet of gas. Thus the desired information is read directly from the chart without calculation.

The background of the principle of the spiragraph is purely mathematical, and is theoretically precise because no approximations are involved. Its operation is also purely mathematical in principle, though in service no more mathematics is evident than there would be in using a 12-inch rule to measure the width of this page;—in fact, the operation of the spiragraph is merely a measuring process as far as needs to be known by the operator. He simply "reads" the measurement of the high of the differential line for the hour, and the reading is the cubic feet of gas that passed the orifice during the hour.

Therefore, the procedure in "calculating" a chart, (when using the spiragraph), is merely a sequence of three simple and rapid acts repeated for each hour of the chart. These acts are:

(1) "Set":—(i.e., Revolve the spiragraph on the chart, bringing it to rest with the setting curve of its lower disc intersecting the averaged height of the static-pressure line.)

(2) "Read":—(i.e., Read on the family of spirals of the upper disc, the averaged height of the differential line.)

*Presented before the Southern California Meter Association, June 22, 1933.

(3) "Write":—(i.e., Enter the reading on the margin of the chart as cubic feet of gas that passed during the hour.)

When this has been done for the twenty-four hours, all the marginal entries are added to obtain the total cubic foot flow for the day.

This, the operation of the spiragraph is exceedingly simple. But what is really taking place is this:—The spiragraph is solving for each hour the familiar, basic orifice meter equation,

$$Q = C \times \sqrt{hp}$$

because the height of the differential line, as measured with the spiragraph, *is* the numerical value "Q" of this equation.

To show how a simple act of measuring brings about the solution of an equation, the form of which indicates the necessity of multiplication and square root extraction, the equation must be transposed into the equivalent form:

$$Q \text{ cubic feet} = h \times \left[\left(\frac{c\sqrt{p}}{\sqrt{h}} \right) \text{cubic feet} \right],$$

in which new form it indicates that if a sequence of units of individual value $[(c\sqrt{p} \div \sqrt{h})$ cubic feet] is measured, the total measurement will be "Q" if there are as many such units as the numerical value of "h".

To illustrate this: If a page which is 9½ inches, or units wide, were measured with such a rule as would show each inch unit to have the value 2.54 lesser units, (merely an ordinary centimeter rule), the total of the lesser units (i.e., the reading of the rule) would be 24.43 centimeters—which is the width of the page in centimeters, obtained by measuring without calculation.

This simple act of measurement involves the following equation indicating multiplication:

W centimeters = 9½ x [(2.54) centimeters].

We may note the similarity between this equation and the spiragraph equation, and so be prepared to comprehend how the common orifice meter equation, though it indicates two multiplications and one square root extraction, may be solved by one act of measuring, in which the *differential height only* is measured.

But there is this outstanding difference between the equation for measuring the width in centimeters of the page and the spiragraph equation: The parenthesis of the former is a constant (2.54), while the parenthesis of the latter is a variable, $(c\sqrt{p} + \sqrt{h})$. This has an important significance, namely; one measuring scale will suffice for measuring different widths of pages, but, for measuring the different heights, h, of the differential line, many measuring scales must be at hand from which the appropriate one must be selected before the measuring may take place. In fact, an almost infinite number must be at hand because the value of the parenthesis represents the size of the units of the scale and this value is subject to vast variation in value because its factors, C, p and h, have fairly wide ranges on individual numerical values.

There is a peculiar significance in the fact that the h, which represents the differential height and is the unknown height that is to be measured, appears also in the parentheses,—a significance that at first thought seems to imply impossibility. A measuring scale must be selected before the differential height, h, may be measured; and the differential height, h, must be measured before the measuring scale may be selected. In other words, the selected scale must be the one whose units incorporate the correct value, h, which is not known until measured but must be known before selecting the scale.

In the spiragraph this apparent impossibility is taken care of by performing as one act the two separate acts of selecting a scale and measuring the height, h. This simple expedient makes it unnecessary that either act must be done ahead of the other. This is the true secret of the spiragraph and is the discovery that made possible its development as an infinite series of scales of progressively different sized units.

The matter of including, in the selection of a scale, due consideration of the value of the C of the unit is also neatly taken care of. The lower disc contains a "coefficient setting line". If this disc is revolved with reference to the upper disc until this "line" indicates on the numbered curves of the upper disc the numerical value of the coefficient and the two discs are then locked in this position, the value of the coefficient is thereby introduced into the unit of any scale thereafter selected.

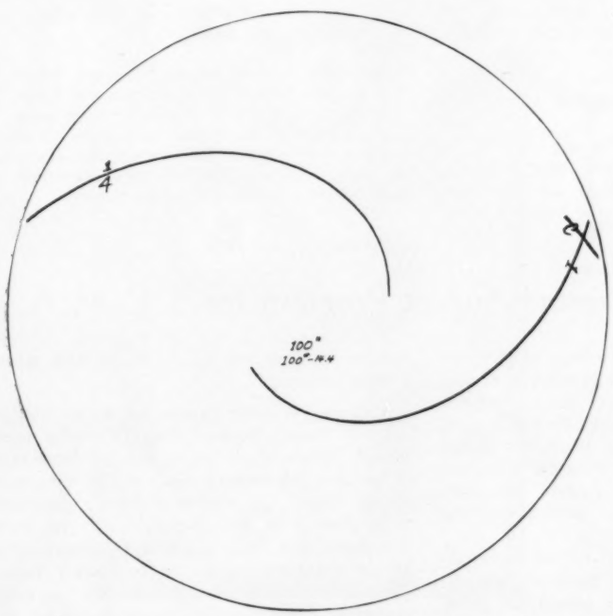
In this connection it should be noted that if unity (i.e., 1.000) is set into the spiragraph as a coefficient the spiragraph then reads, at the height of the differential line, not the cubic feet of gas, but only the extension. This may be shown by:

$$Q = 1 \times \sqrt{hp}$$

Therefore, Reading $= \sqrt{hp}$

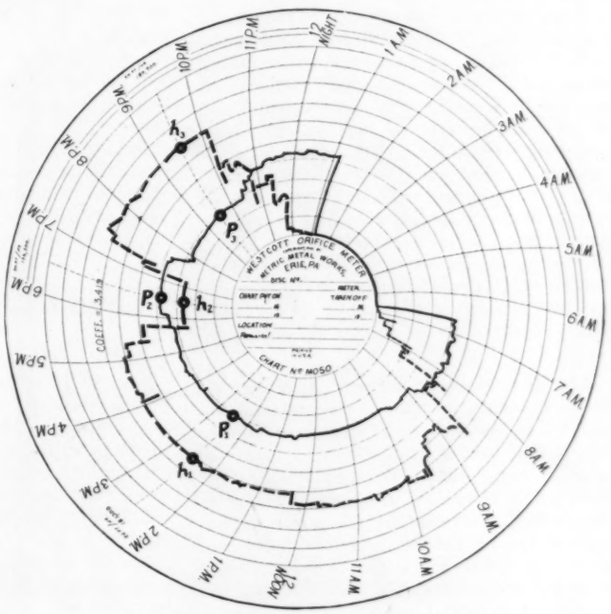
Extracting the square roots of h and p is taken care of by the peculiar shapes of the curves. The range of the recording instrument (i.e., whether 10-inch, 50-inch, etc.) is taken care of by the relation between the position of the coefficient setting line and that of the static setting curve; both of which are on the lower or "setting" discs. This requires that for charts from different recorders, different setting discs must be used, except that any one setting disc may have several "coefficient setting lines", thus making the same spiragraph usable for charts from recorders of several different ranges.

The range of the pressure pen (i.e.,



SETTING DISC

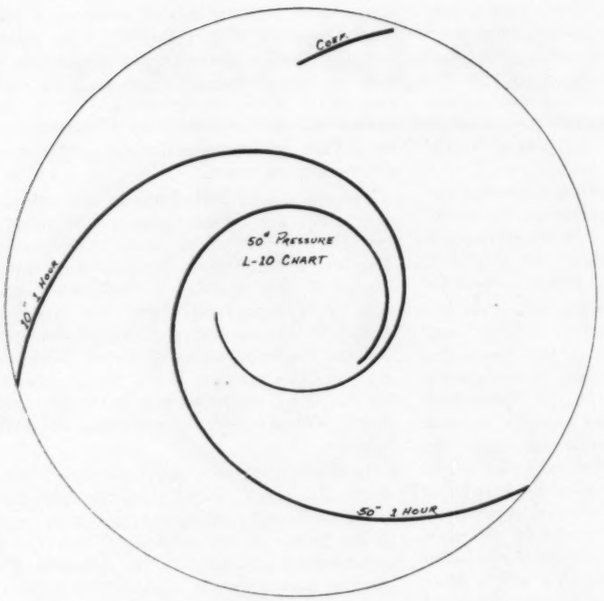
Showing the difference in position, with reference to the coefficient setting line, of "setting curves" for reading charts by the hour or by 15-minute periods. Both curves (as well as curves for one-half hour, two hours, etc.) may appear on the same setting disc, thus making the spiragraph useful for reading a chart by hours, quarter-hours, or time periods of any length.



WESTCOTT ORIFICE METER CHART

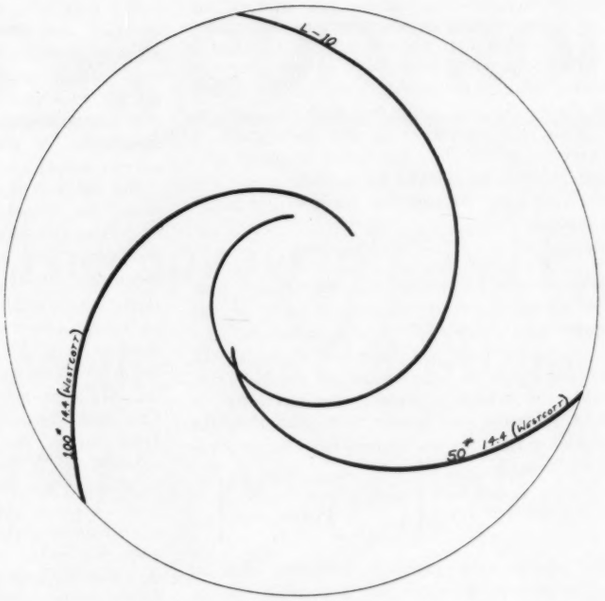
Dash line = Differential record.
Full line = Static pressure record.

Points h_1, h_2, h_3, are located at elevations that represent the average height of the differential line for the hour. Points P_1, P_2, P_3, represent the average height of the static line for the hour. Both are located on the half hour line.



SETTING DISC

Showing the difference in position, with reference to the coefficient setting line, of L-10 setting curves for reading 50-inch and 10-inch charts. Both curves, as well as others, may appear on the same setting disc, thus making the spiragraph useful for L-10 charts from meters of different differential ranges.



SETTING DISC

Showing the three different shapes and lengths of setting curves that are required for the ordinary 100-pound and 50-pound Westcott charts and for the L-10 Westcott chart. These curves as well as others may appear on the same setting disc, thus making the Spiragraph useful for ordinary charts from meters equipped with different pressure springs as well as for L-10 charts.

whether it is for 50 pounds maximum, 100 pounds maximum, etc.) is taken care of by the *shape* of the setting curve. Therefore, charts from recorders equipped with different pressure springs require that different setting discs be used, except that one setting disc may have any number of setting curves, thus making one spiragraph usable for charts from recorders equipped with different pressure springs.

The two preceding paragraphs refer to ordinary charts, as contrasted with the square root extracting "L-10 charts". If L-10 charts are used and if (as is conventional practice) the so called "instrument factor" is multiplied into the "gas coefficient", (represented by C in the orifice meter formula) and this "L-10 gas coefficient" be the one that is set into the spiragraph, then the matter of differential range and pressure spring range is taken care of in the "L-10 gas coefficient", and one setting disc, having but one setting curve, will suffice (with its superimposed reading disc) for the calculation of all charts, regardless of the differential range or pressure range of the recorder on which they were used.

Also, if L-10 charts are used, it is then no longer necessary to "set" on the pressure line and "read" the differential line as previously stated, but "setting" and "reading" may be done at either line. That is, whether the differential height or the static height is "measured" to obtain the cubic foot "reading" makes no difference, as the "measurement" of either gives the same "reading" provided the other is the one to which the spiragraph is "set".

There is one more matter of interest that deserves reference. Under some circumstances it is advisable to calculate charts by 15-minute periods, or to calculate parts of charts, (wherein the differential or static lines change extensively) by 15-minute or possibly 30-minute periods. Under other conditions it may be permissable to estimate the average heights of the two chart lines for periods of 2, 3, or even 24 hours. Or there may be conditions where it is desired to measure gas in transit that is purchased according to 1 standard foot (such as the foot as of 60° F. and 14.73 lbs.) and which is to be sold according to a different standard foot (such as 80° F. and 14.4 lbs.) and where the measurement is desired in both units. Or there may be any number of special cases for which extension books are not available. The spiragraph accommodates itself to all of these to the end that it eliminates all calculations.

By including on the setting disc one or more different curves, or the same curve in one or more different positions, all such combined or peculiar cases may be handled without confusing calculations. One spiragraph suffices and the clerk using it is put to no more complicated work than is implied by the directions for use, which are: "set", "read", "write".

As to the speed obtainable with the spiragraph, little need be said. When calculating charts by the usual method the following steps are necessary of which the steps in italics are not required when using a spiragraph. (The case cited is where hourly cubic feet are calculated and then added to obtain daily cubic feet).

Read differential height for each hour.
Write the above on a calculation form.
Read static pressure height for each hour.
Write the above on the calculation form.
Enter an extension table with the above two readings and take out extension.
Write this on the calculation form.

(Continued on Page 87)

Union Oil Sponsors August Program for S. C. M. A.

THE first of several meetings to be sponsored by individual companies was held by the Southern California Meter Association on August 24, at the Lakewood Golf Club, Long Beach, Calif. With the Union Oil Co. as sponsor, and program arrangements in charge of R. F. Angell, the meeting resulted in one of the most interesting sessions of the year.

President C. B. Heartwell turned the meeting over to F. E. Bradley, program committee chairman, who in turn passed the gavel to Mr. Angell. Frank Stevenson of the Union's Wilmington Refinery first favored the gathering with several specialty vocal and piano numbers, following which Jimmy Thompson, golf professional of the Lakewood club, gave Association golfers some valued tips on how to get rid of slices and other golfing ailments.

Mr. Angell next introduced A. K. Hegeman of Smith Booth Usher Co., who presented an excellent paper on fundamentals of natural gas compression. K. E. Kingman of the Union Oil staff brought the program to a close with his discussion on "Modern Gasolines and Why", treating interestingly of the requirements in modern motor fuels, gasoline testing practice, and other aspects. Questions from the floor were answered by both speakers following their remarks.

Last month's S.C.M.A. golf tournament winner was announced by Gordon Greene, the cup going for the month to M. E. Carrico, Southern California Gas Co.

COMMITTEE:
DOUGLAS BUCKLER . SO. CALIF. GAS CO.
J. EARL JONES . . . SEATTLE GAS CO.
A. C. JOY (CHAIRMAN) . . P. G. & E.
F. U. NAYLOR . . . . . P. G. & E.
D. L. SCOTT . . . . L. A. G. & E. CO.

P. C. G. A. NEWS

HEADQUARTERS:
PACIFIC COAST GAS ASSOCIATION
447 SUTTER STREET SAN FRANCISCO
H. L. MASSER (L. A. G. & E. CO.) PRESIDENT
CLIFFORD JOHNSTONE, MNG. DIRECTOR

CO-OPERATIVE ADVERTISING

SEPTEMBER will be the 49th consecutive month of Coastwide co-operative trade journal advertising. Again more than 200,000 readers will be forcefully reminded that **Gas is the modern industrial fuel—quick, clean, economical!** Convincing testimonials . . . photographic evidence . . . friendly offers of cooperation and service . . . to 11 important classifications:

MISCELLANEOUS INDUSTRIES: Pacific Factory; Pacific Dairy Review; Western Confectioner & Ice Cream News; Western Baker; Pacific Laundry Journal & Dry Cleaner; Western Machinery & Steel. RETAILING: Western Appliance Retailing; Western Plumbing & Heating Journal. ARCHITECTS, BUILDERS: Architect & Engineer; California Arts & Architecture; Pacific Builder & Engineer; Southwest Builder & Contractor. HOTELS, RESTAURANTS: Keeler's Hotel Weekly; (others alternated).

OUR TECHNICAL NEWS SERVICE, by furnishing accurate, interesting material on gas utilization, has placed an impressive number of articles with trade journal editors. With 66 as the record to July 1, 10 more were published during July—or a total of 76 for the first seven months of 1933.

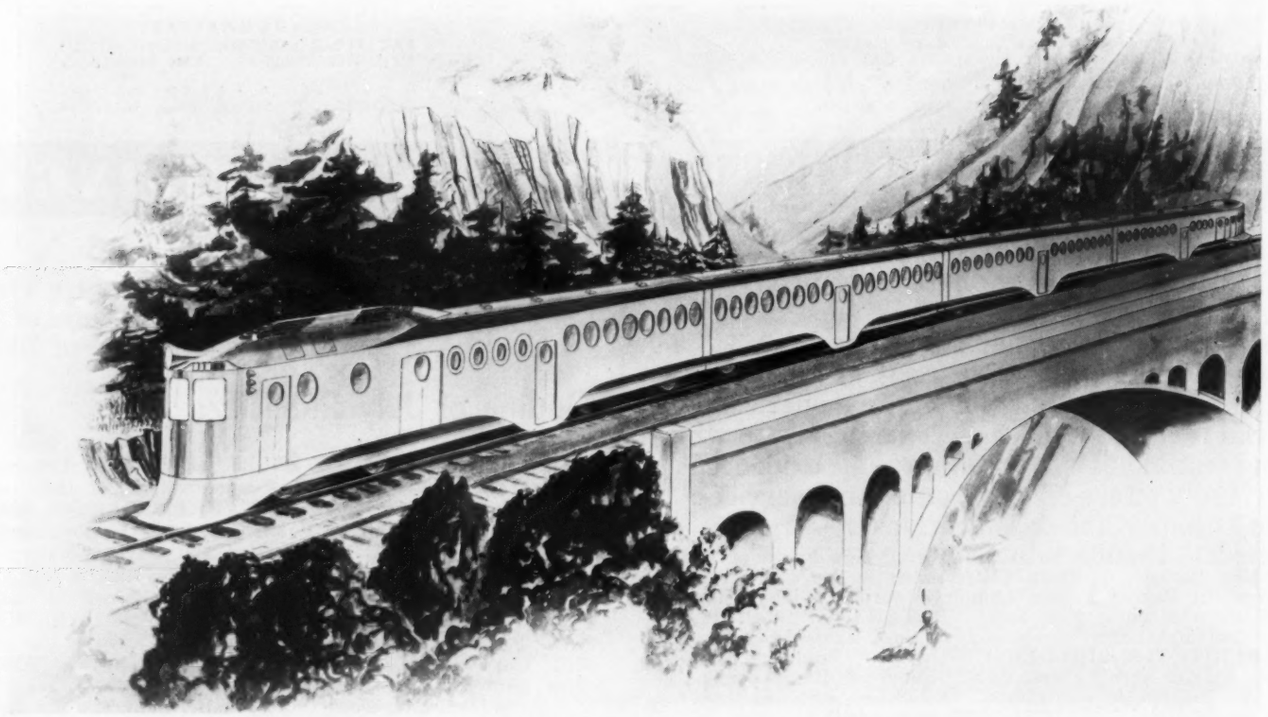
Outline of July Publicity:

KEELER'S PACIFIC HOTEL REVIEW: **"An Automatic Refrigerator that Burns Gas"**—description of new air-cooled model. WESTERN RESTAURANT: **"Frank Miller puts Red Lion on Map in Seattle"**—gas fuel in popular restaurant; (2) **"New Gas-fired Deep Fat Fryer"**—automatic temperature control. WESTERN MACHINERY & STEEL: **"The Manufacture of Automobile Axles"**—Gas-fired equipment in plant of Edwin L. Stanton, Los Angeles. WESTERN BAKER: **"Cake is King"**—Gas equipment used at General Mills Cake School, San Francisco. PACIFIC FACTORY: **"Gas Heat Used in Washington Plant for Sterilization of Cereals"**—Dina-Mite Food Co., Spokane; (2) **"Western Company Develops New Gas Heater"**—Describing radically new water heater. WESTERN FURNITURE RETAILING: **"Gas Water Heater Drive Sells 4,179 Units"**—results of annual spring campaign. PACIFIC BREWER and VINTNER: **"Gas-fired Boiler Installation at Rainier Brewing Co., San Francisco."** PACIFIC COAST CHEF: **"Cake Baking Course"**—Gas bake ovens used in General Mills cake school.

★ ★ NEW ADS

★ A Seattle Candy Manufacturer Endorses Gas (Western Confectioner).

★ "Gas exclusively" in a Southern California Paper Mill (Pacific Factory).



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ODORLESS, SMOKELESS FUEL

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Now Adopted Rail Motor-Car Fuel
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BUTANE is an efficient, economical substitute for manufactured gas, natural gas, and electricity for domestic and industrial uses including heat-treating, cutting, welding, refrigerating.

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BUTANE • PROPANE NEWS

Vol. 3, No. 9 September, 1933

A Cylinder Jacket Testing Installation

By W. G. WATKINS

Skelgas Company, Kansas City, Missouri

WITH the passing of time a large number of operators in the liquefied petroleum gas industry enter a new operation, Quinquennial Testing of Cylinders. This operation is one of considerable magnitude and one which cannot be readily speeded up excepting in the stages of preparing the cylinders for testing and the subsequent re-equipping of the cylinders for service.

The foregoing limitation is an important factor in the design of the plant herein mentioned. In this plant the attempt has been to design an installation which could be worked efficiently with only one operator, or operated with one operator and an assistant, as conditions demanded, and without an appreciable loss in efficiency.

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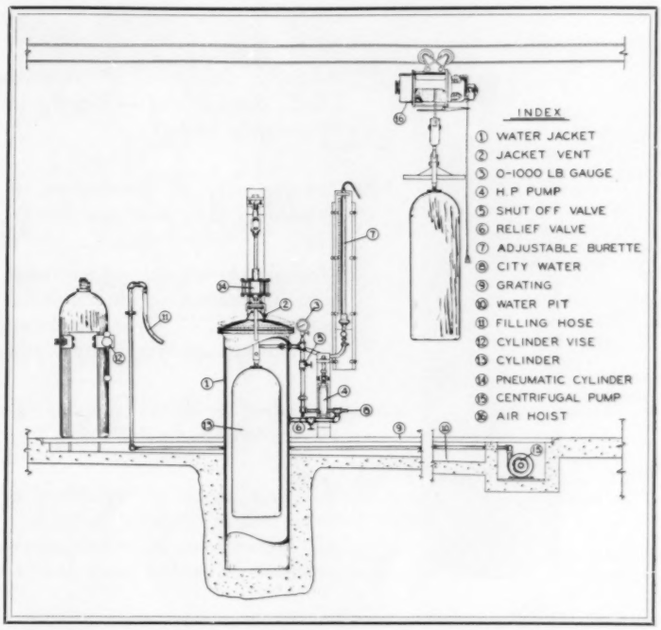
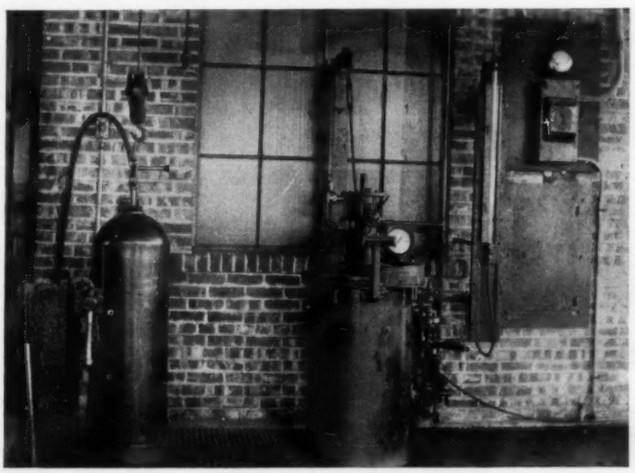
AT RIGHT

Cylinder jacket testing layout.





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AT LEFT

Fig. 1—General view of testing installation.

The stock of cylinders at individual points in most instances is not adequate to permit holding back large quantities of cylinders for batch testing. Consequently, the capacity of the testing installation must be as flexible as possible to meet these varying conditions.

One of the opportunities for increasing the speed of operation is in the clamping of the cover on the testing jacket. To speed this up and eliminate leaks by the application of a uniformly distributed pressure of the sealing gasket, a pneumatic cylinder is employed to raise, lower, and clamp the cover of the testing jacket. This not only saves time but permits the operator to avoid water spillage when the cover is released. In the case of installations equipped with hand clamping covers, the water spillage made it necessary for the operator to wear a rubber apron and rubber boots, both of which handicapped his ability as well as being inconvenient.

The cylinder vise shown at the left of Fig. 1 is a special device which clamps the cylinder firmly without damaging it. The device is really a chain pipe vise re-adapted to an I-beam support with a coarse pitch screw. The use of a pneumatic cylinder was considered for this application but finally discarded as the saving of time and labor was negligible. The vise is a much used portion of the installation and careful consideration should be given to its location to avoid excess handling of the cylinders.

Water for the installation is handled by an explosion-proof pumping unit located in one corner of the water pit. This permits uniformity of water temperatures for testing, which assists in reducing temperature effects on the test. In this particular operation the cost of water for testing, if not recovered, was an appreciable item, but was not as great as the cost of handling waste

CYLINDERS
FOR
BOTTLED GAS

Properly Designed in Accordance with I.C.C. Regulations — Rigidly Inspected — Thoroughly Tested.

The majority of distributors of Liquefied Petroleum Gas now use Scaife Cylinders.

Modern Manufacturing Methods combined with an increasing demand have resulted in Scaife I.C.C. Cylinders being the most economical cylinder in use today.

Cylinders built to meet each purchaser's service requirements.

A large stock of cylinders of standard sizes insures prompt service. 130 years of experience in manufacture of steel products is behind each Scaife cylinder.

FOUNDED 1802

WM. B. SCAIFE & SONS Co.

Oakmont, Pa. (Pittsburgh District)

New York Pittsburgh Chicago

Eliminate COLD 70°

The Low Limit Control System enables your gas burner to deliver full performance by keeping enough heat in radiators and hot air registers to prevent air stratification or "Cold 70°". A low priced control with a ready market. Minneapolis-Honeywell Regulator Company, 401 East 28th Street, Minneapolis, Minn. Branch offices or distributors in all principal cities

MINNEAPOLIS-HONEYWELL
Control Systems

water; and both these conditions necessitated the use of a recovery system.

The air hoist and trolley used for raising and lowering cylinders is centered over the testing jacket and located off center with regard to the vise, thus permitting a free swing of the cylinder when being handled between the vise and the cylinder testing jacket.

In normal operations the operator in the charging plant eliminates the cylinders due for testing and removes the cylinder valves for inspection and repair.

The operator of a testing installation (after testing has been started) empties the pit of water at the close of the day's work by filling the cylinders to be tested with this water, the total volume of water being about 150 gallons.

Cylinders are then wheeled to the vise where the special spud fitting is installed in the cylinder. The cylinder is then raised with the air hoist and lowered into the testing jacket and connected to the high pressure water supply. After the purging of air bubbles from around the cylinder, the jacket cover is applied by swinging it into place and applying air pressure to the pneumatic cylinder.

Testing of cylinder is then conducted according to the rules and regulations prescribed by the Bureau of Explosives in Agent Dunn's tariff No. 1, as well as in accord with any special instructions which may be issued in specific instances in regard to stenciling of cylinders, etc.

The graduated measuring burette employed is of the adjustable type with an adjustable brass scale calibrated to the particular burette on which it is used by actual filling of the ungraduated burette with known volumes of water and marking the brass scale accordingly to read in cubic centimeters. Zero on the burette corresponds with the zero indicated on the scale which, in turn, corresponds with the level of the vent pipe in the cover of the cylinder testing jacket. The use of the adjustable type measuring cylinder or burette compensates for the effect of any small quantities of air mechanically entrapped inside the cylinder testing jacket.

After testing the cylinder in accordance with regulations, manipulation of a two-way air valve raises the cover, which is simultaneously swung to one side by the operator.

The high pressure water connection from the high pressure pump to the cylinder to be tested is made quite accessible and requires only a moment for loosening, after which the cylinder is lifted from the jacket by means of the air hoist and lowered into the vise where the spud fitting is removed.

The cylinder full of water is then wheeled to the cylinder dumping and purging equipment (not shown in the illustration), where the water is removed and the cylinder re-equipped for service.

The installation shown in the illustration is, of course, made to fit existing conditions. Capacity of the plant is about 4 to 5 cylinders per hour for one operator and 8 to 10 cylinders per hour for two operators. It should be borne in mind, of course, that testing time varies quite widely, for when a cylinder is found to fail to pass the test considerable time is involved in its handling. Also it is not always possible to make

up the connections absolutely tight on every cylinder to be tested; this results in leakage, which must be traced down and eliminated and the cylinder subsequently tested.

A. E. DeBurn Joins American Liquid Gas Co. Organization

A. E. DeBurn

Arlan E. DeBurn, for a number of years engaged in gas equipment sales and engineering work on the west coast, has become associated with the American Liquid Gas Co., butane-propane engineering firm of Los Angeles, Calif., in the capacity of sales engineer.

Mr. DeBurn was in charge of gas industry equipment sales for Pacific Pipe and Supply Co. for several years, leaving that organization to join the Southwest Welding and Manufacturing Co. staff. Harold W. Smith is president of American Liquid Gas Co.

Wisconsin Rapids Gas Co. Now in Permanent Location

PERMANENT headquarters have been leased by Wisconsin Rapids Gas Co. in the Hamm Building at Wisconsin Rapids, Wis., with renovating and remodeling scheduled to be completed by September 1, when the gas company will move in, according to Lee H. Barker, president of the company.

The new offices will include a display floor for gas ranges, water heaters and refrigerators and private offices for the gas company personnel.

Wisconsin Rapids has been designated as headquarters for operations of Liquified Natural Gas Corp. of Minneapolis, Minn., parent organization, in a program for taking liquified petroleum gas service to a score or more of towns in Wood, Portage, Juneau, and Waushara counties.

The company plans to build a plant and distribution system in Wisconsin Rapids and to serve bottled gas on a utility basis in the other towns.

Articles of incorporation for Wisconsin Rapids Gas Co. have been filed with the secretary of state at Madison with the following men named as incorporators: M. S. King, Leonard J. Bethke, L. P. Daniels, Frank Henry and Geo. E. Smith, of Wisconsin Rapids; H. H. Voss, Nekoosa and Merrill Reeder, Wautoma. Authorized capitalization is $60,000.

Design for the company's distribution system has been submitted to the Wisconsin Public Service Commission for approval, by H. H. Henley, engineer for the company.

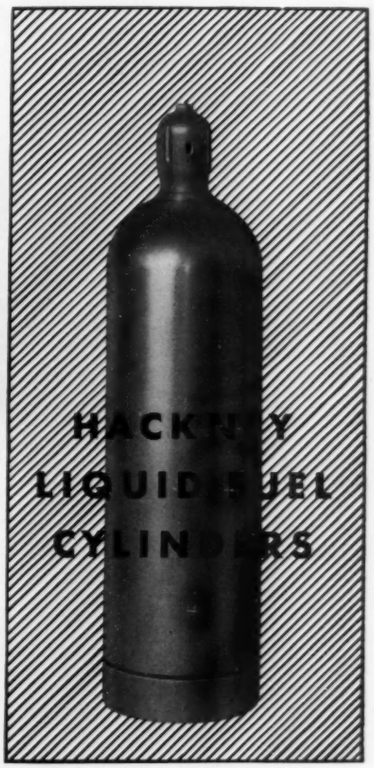
According to Mr. Barker, more than 300 applications were on file on June 1.

Dri-Gas Distributor at Walnut, Ill.

R. H. Tuckerman & Co. of Walnut, Ill., has been appointed by the Illinois Bottled Gas Co. of Chicago as representative for the sale of Dri-gas in that vicinity.

THE LEADER

There are TWICE as many Hackney Liquefied Petroleum Gas Cylinders in service as all others COMBINED.



To users of cylinders, Hackney offers a design and manufacturing service, based on wide experience—meeting the varying needs of the country's largest industries.

Since the first, **Hackney has designed and built cylinders for Butane, Propane, and Butane-Propane mixtures.**

Superior design and rigid standards distinguish Hackney cylinders.

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208 S. La Salle St. Bldg., Room 1185, Chicago, Ill.
1363 Vanderbilt Concourse Bldg., New York, N. Y.
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POWER Ensign Carburetor ECONOMY

BUTANE GAS
NATURAL GAS
CARBURETORS

The Ensign Carburetor Co., Ltd., has developed suitable equipment for the handling of Butane gas or Natural gas in engines designed for this purpose to give the maximum efficiency in operation and economy.

The Butane equipment consists of a special carburetor, regulator, heating attachment and pressure reducing valve.

The carburetor is of the plain tube type, and is designed to produce the correct mixture of air and gas at all loads and speeds on all types of engines. It has no moving parts or valves.

WRITE FOR LITERATURE

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Six More Butane Installations for Aqueduct Camps

USE of butane in construction camps now being created for major projects in the west continues to gain headway. Following the original installation in July of a butane plant at the Thousand Palms camp for the Metropolitan Water District of Southern California, now engaged in construction of the Colorado River Aqueduct, the District has let contracts for similar plants at Desert Center, Wide Canyon, Pushawalla, Berdoo, Fargo, and Yellow, on the aqueduct route. American Liquid Gas Co., Los Angeles, which installed the first plant at Thousand Palms, has the contract for the above additional camps and was completing the Desert Center installation late in August. First butane deliveries at Thousand Palms were also due late in August.

Distribution systems in the various camps are being laid by the Metropolitan Water District.

At each camp 4,000-gallon butane storage is specified, together with a gas plant of rated capacity exceeding 1,000 cu. ft. per hour, undiluted butane service being rendered. Each camp is equipped to house about 150 men, and gas service is depended upon for cooking, water heating, refrigeration, and space heating. Work of plant installation is under way for all of the camps, and the district expects to be on gas service some time during the first 10 days of September.

Change to Butane-Air Being Considered for So. Ore. Gas Corp.

Southern Oregon Gas Corp., headquarters at Medford, Ore., is giving consideration to changing its oil gas system over to butane-air service. The company serves Ashland, Medford, Grants Pass and Roseburg, Ore., and the present plan is to convert the Grants Pass plant to butane-air first, to secure adequate operating data before the other change-overs are made.

It is planned to use the Heller gas mixers, introduced during the past year by the Utility Development Co., San Francisco, of which John K. Heller is president. Butane-air gas of higher B.t.u. than the present 550-B.t.u. oil gas will be served, in order to make changing of orifices for appliances unnecessary. Any rate adjustment called for due to change in heat value will be handled through use of a multiplier, rather than a revision of rate schedules, according to present plans.

J. B. Green Plumbing Co. Serving Sarasota With Iso-Butane

J. B. Green Plumbing & Equipment, Inc., Sarasota, Fla., distributors of "Green's Fuel" is marketing through the company's bottled gas distributing system, a formula for iso-butane with dew point 10 degrees above zero, which is particularly adaptable for use in the southern states. The new type gas is sold by the gallon with a magnetic gauge indicating the number of gallons in the customers storage tank.

Bottled Gas Program Begun in Mexico City, Mex.

Compania Mexicana de Petroleo "El Aguila", S. A., Mexico City, Mexico, is initiating a campaign for the sale of bottled propane and butane gas in Mexico City, said to be the first gas distribution of its type in the Republic.

Butane Engine Equipment Announced by Ensign

The Ensign Carburetor Co., Ltd., Los Angeles, Calif., has developed a new line of special equipment to utilize butane or natural gas in internal combustion engines, the butane equipment consisting of a special carburetor, regulator, heating attachment and pressure reducing valve. The carburetor is of the plain tube type, without moving parts or valves; the regulator is designed to maintain constant outlet pressure against an intake pressure which may vary over a wide range.

Southern Union Gas Co. May Build 25-Mile Lateral

Prospects of a new 25-mile extension from Southern Union Gas Co.'s San Juan Basin-Albuquerque line are seen in the application of mining interests of New Mexico to the Reconstruction Finance Corp. for funds to lay the line.

The object of building the lateral would be to serve natural gas to the mining load in the Cochiti district for smelting gold and silver ores, and in the Bland district for generating electric power for running the ore trains and operating other machinery in the mines and mills and furnish light and power for the camps.

Oklahoma Natural District Office Sets No-Lost-Time Accident Record

Oklahoma Natural Gas Corp.'s Oklahoma City district organization established a record for the 12 months extending from June 1, 1932 to June 1, 1933. During this period there was no lost time accident in that district, where employment averaged 142 employees daily during the year.

Inland Pipeline Co. Applies for Line Construction Permit

Inland Pipeline Co., Emporia, Kan., has applied to the state corporation commission for a certificate of convenience and necessity authorizing it to operate a gas pipe line from the Burrton field to Emporia, Kan. The city is already served with natural gas by the Kansas Electric Power Co.

New Oklahoma Gas Co.

The Cheyenne Gas Co., Cheyenne, Okla., has filed application to operate in the state of Oklahoma.

Here and There With Western Gas

AT the right we see a score or more gas men of the West, caught by the camera during the past month, for the most part at their company headquarters. Craig Espy, vice-president of *Western Gas,* is swinging around the gas company circuit on a summer field trip, touching principal natural gas centers from coast to coast. This page for the next few months will present typical views taken by him during his contacts with *Western Gas* readers.

Read from left to right to identify men in the accompanying views.

1. F. F. DOYLE, manager natural gas division, Pacific Gas and Electric Co., San Francisco, Calif.

2. WILLIAM H. HORNBUCKLE, distribution superintendent, and ROY H. EAST, assistant distribution superintendent, Utah Gas & Coke Co., Salt Lake City. Portion of humidification and oil fogging apparatus can be seen in view; there are 21 similar installations in Salt Lake, and 12 in Ogden.

3. J. J. FERRARI, gas superintedent, Sierra Pacific Power Co., Reno, Nevada, and S. G. RICE, gas works foreman. Ferrari came to Reno four years ago from Puget Sound Power & Light Co. at Bellingham, Wash.

4. In this photo, taken at the Omaha, Nebraska, offices of the Northern Gas and Pipe Line Co., are JAMES L. GRIFFIN—superintendent of measurement, JOHN RIFFEE—superintendent of compressor station at Clifton, Kansas, E. R. DUREE—superintendent of transportation, J. P. BRISTOW—engineer, all of Northern Gas and Pipe Line; JEB. GIBBONS, representative of S. R. Dresser Mfg. Co.; and H. J. CARSON, chief engineer, Northern Gas and Pipe Line.

5. Heads of Denver gas sales divisions: F. M. CHELF, superintendet house heating division; C. A. BIGLER, superintendent domestic gas division; C. W. GALE, superintendent commercial and industrial division, Public Service Co. of Colorado.

6. R. G. MUNROE, gas new business manager, Public Service Co. of Colorado.

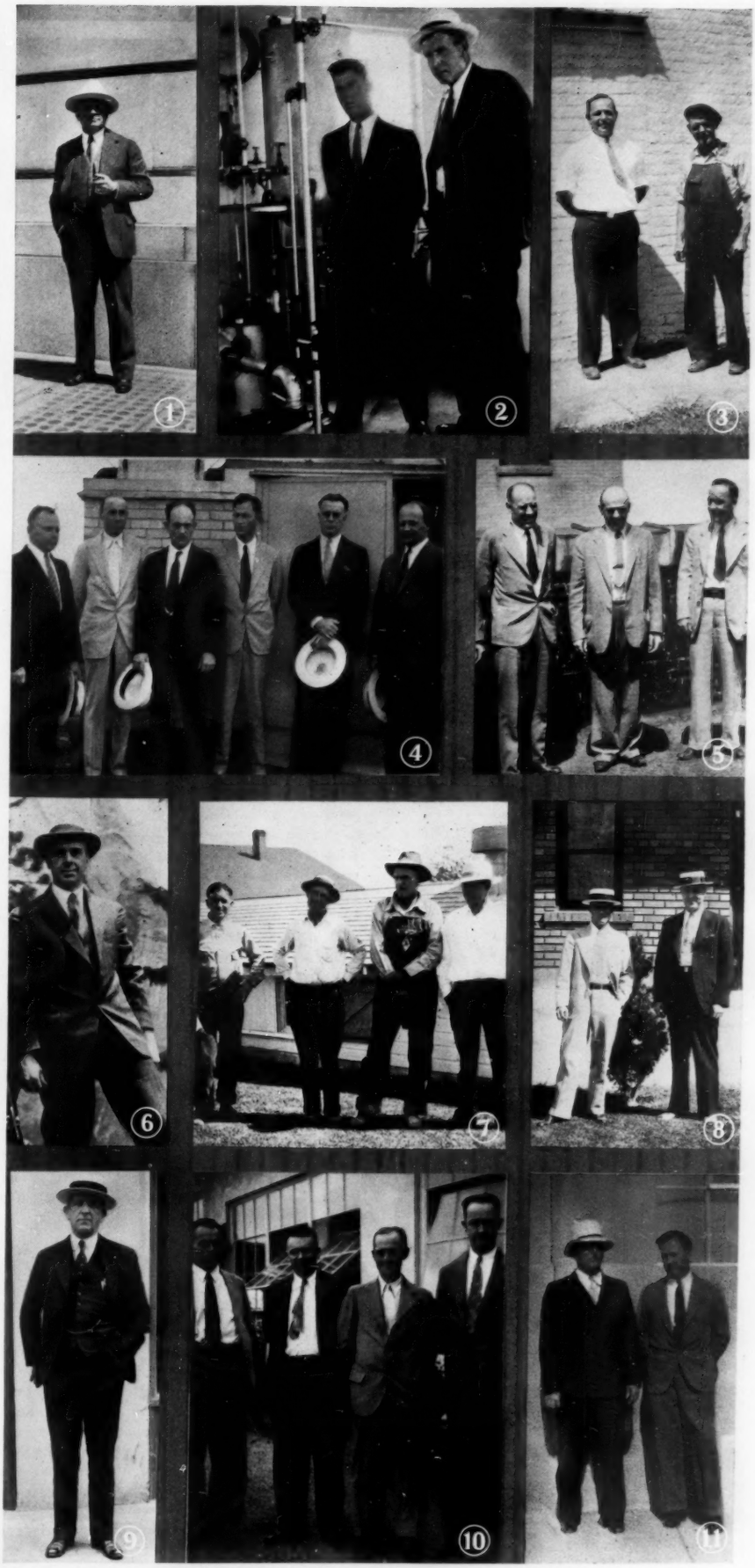
7. J. C. RYAN, HENRY SMITH, W. E. COHAGEN and C. A. STAMM, foreman, Rocky Mountain Gas Co., Rawlins, Wyoming.

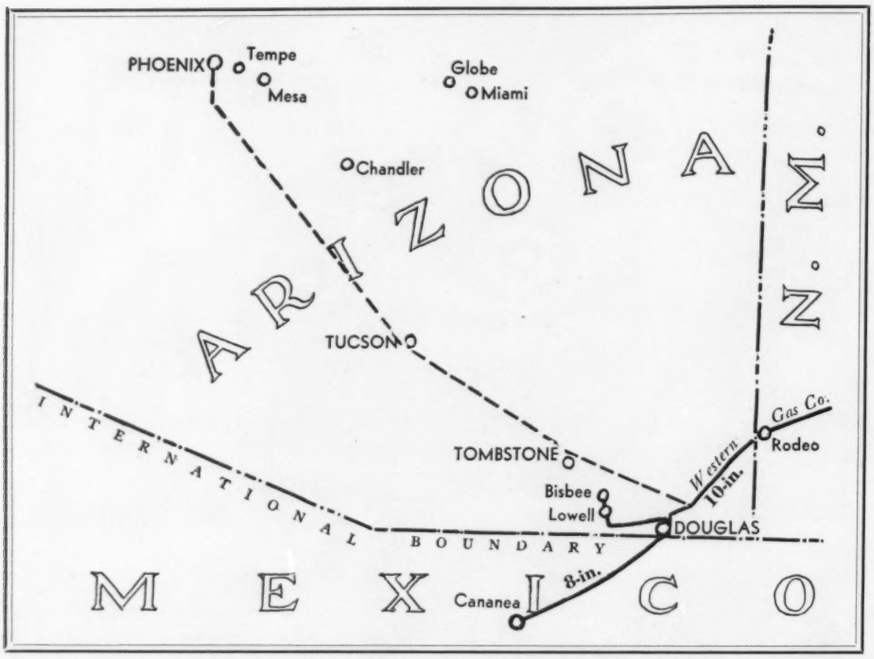
8. J. D. ROBERTS, operating vice-president, Utah Gas & Coke Co., Ogden Gas Co., and Wasatch Gas Co.; J. J. DYER, comptroller, Lone Star Gas Corp., Dallas, Texas. (Photo taken at Salt Lake). Roberts has recently assumed management duties of Utah properties following resignation of L. Fitzpatrick, vice-president and general manager.

9. GEORGE P. EGLESTON, general manager, H. R. Basford Co., San Francisco; vice-president in the current Pacific Coast Gas Association administration.

10. G. J. HECKENDORN, assistant engineer of gas distribution; BRUCE MACCANNON, superintendent gas measurement; GEO. WEHRLE, superintendent gas department; ROBERT H. TAYLOR, gas engineer—all with Public Service Co. of Colorado at Denver headquarters.

11. ELTING HENDERSON, assistant general superintendent, Southern California Gas Co.; K. C. TOMLINSON, assistant manager, Pacific Meter Works, located at Los Angeles.





Sketch of route for new 10-inch carrier to serve Phoenix, Tucson and Tombstone, Ariz., shown as a heavy broken line. Solid line shows existing system of the Western Gas Co.

Tucson-Phoenix Line Gets Under Way

CONSTRUCTION was expected to begin during the last days of August on the Douglas-Tucson-Phoenix carrier of the Western Gas Co., El Paso, Texas, with funds to the extent of $2,200,000 having been allocated for the purpose by the Reconstruction Finance Corp. through the American Mortgage Co. of El Paso, according to H. G. Frost, vice-president and general manager of Western Gas Co. The new natural gas transmission line will be approximately 215 miles long, of 10¾-inch pipe, and will follow a direct route from a point a few miles north of Douglas, present terminus of the company's main line from the Jal field in New Mexico to Arizona mining districts, direct to Tombstone and Tucson, and from there will follow the general direction of the Tucson-Pichaco road to Phoenix.

Pipe has been purchased from A. O. Smith Corp. of Milwaukee, Wis., and Republic Steel Corp. of Youngstown, Ohio, and contract for construction of the line has been let to Bechtel-Kaiser Co., Ltd. and Henry J. Kaiser Co. of California who estimate that from 1,500 to 2,000 men will be put to work on the project, which will take four or five months to complete. Both of the construction firms and the Western Gas Co. planned to open offices in Tucson and Phoenix immediately.

The change-over to natural gas at Tucson will involve about 5,500 meters on the system of the Tucson Gas Electric Light & Power Co., now on oil gas service, and according to Max A. Pooler, vice-president and general manager of the company, approximately $100,000 will be spent adjusting appliances and meters for the new gas. The Tucson company will pay a gate rate of 4 cents per therm to Western Gas Co.; the gas will traverse a distance of about 540 miles from the Jal field in eastern New Mexico, source of the supply for the new line.

Edward H. Coe, vice-president and general manager of the Central Arizona Light and Power Co. states that introduction of the new fuel in Phoenix will mean an expenditure of about $500,000 over the next four years, including new mains and feeders, maintenance of existing mains, and the conversion of equipment and appliances to the use of natural gas.

Plans Call for Completion of Line to Serve Big Rapids, Mich.

Construction of a 15-mile line from the Mecosta gas field to serve Big Rapids, Mich., with natural gas, was expected to be completed by September 1, according to press reports from the district. Big Rapids Gas Co. has been serving coal gas through 600 or more meters there, and plans to change over to natural gas service on completion of the line.

South Plains Pipe Line and West Texas Gas Co. Merged

South Plains Pipe Line Co., Lubbock, Texas, is now merged with the West Texas Gas Co., according to an announcement early in August by R. F. Hinchey, vice-president and general manager of West Texas Gas Co. Mr. Hinchey states that the action was taken by officers of the two companies to increase the operating efficiency and effect certain necessary economies.

Refrigerator Sales Contest for Gas Campanies Forecast as Success

SUCCESS of the midsummer retail gas refrigerator sales contest now being waged by hundreds of gas companies throughout the country is forecast by Cyrus Barnes, chairman of the Refrigeration Committee of the American Gas Association. The campaign is being sponsored by the Association in collaboration with the manufacturers of Electrolux refrigerators at Evansville, Indiana. Reviewing the progress of the campaign to date, Mr. Barnes states:

"The Refrigeration Committee of the American Gas Association took an unprecedented step when it sponsored a contest among American gas companies to spur gas refrigerator sales during the hot months of the year. The campaign started the first of July and will be continued throughout October. This is the first time in the history of the Association that the industry as a whole has been asked to support a campaign to sell an individual gas appliance.

"Response to the project by gas company sales executives was immediate and enthusiastic. Reports from all parts of the country indicate that there is no diminution in enthusiasm on the part of the sales forces, and that by the time the campaign is finished over 5,000 gas company sales managers and gas appliance salesmen will have complied with the rules and be eligible for the substantial prizes offered by the manufacturers of Electrolux.

"Final reports under contest requirements must be mailed by midnight of November 15, 1933. Prizes will be paid by December 15, 1933. All communications should be sent to 'The Refrigeration Prize Contest Committee, American Gas Association, Graybar Building, New York City.

"The prizes will be awarded as follows: First prize of $750 to the gas company, district office or branch office making the highest record (sale of the greatest number of ice-cubes per 100 retail meters) $200 of which will go to the local manager, and $550 to be divided among the salesmen pro rata; a second prize of $500, of which the local manager will receive $150, the remaining $350 going to the salesmen; a third prize of $250, of which $50 will be paid to the local manager and $200 to the salesmen."

"The Housewife's Friend" Greets Portland Gas Consumers

Portland Gas & Coke Co., Portland, Ore., has recently begun publication of "The Housewife's Friend". The new medium, issued monthly in four-page form, as its name implies is a friendly messenger to company homes, its contents being made up of menus, hints on efficient use of gas appliances, and miscellaneous useful household information.

New Catalog By Killam Gas Burner Manufacturing Co.

Killam Gas Burner Manufacturing Co. of Denver, Colo., announces the publication of a new catalog featuring the Killam Preheated air burner. The catalog will be released from the press soon.

MENU
BREAKFAST

Choice of Fruit

Bacon or Ham & Eggs (A)

Griddle Cakes (B)

Coffee

—o—

(A) Broil Ham or Bacon in Hotzone BROILER.

Put Eggs in pan with Butter, allow to remain in Hotzone BROILER Compartment for one minute. You never tasted Eggs as good before!

(B) Cook Griddle Cakes on Hotzone GRIDDLE. They will be uniformly Golden Brown.

WELSBACH BROILER GRIDDLE

Manufactured By

Welsbach COMPANY

Gloucester, N. J.

50 Hawthorne St.
San Francisco, Calif.

226 S. Wabash Ave.
Chicago, Ill.

STEADY OUTLET PRESSURE *Insured*

In Low Pressure Gas Regulation, successful operation depends upon the flow of gas at an uniform outlet pressure regardless of varying inlet pressure and volume. Line pressure and volume will vary and unless this is taken into consideration in the design and construction of the gas control unit the outlet pressure will also fluctuate. Reynolds, recognizing this important requirement, has built their low pressure regulator with a balanced valve construction that counteracts the effect of varying line pressure by throwing the control of the valve upon the constant pressure side of the unit. This is also the operating principle of the single valve construction. Its simple design and construction, plus the factory test through a wide range of operating conditions, assure you of satisfactory service and long life.

This unit is particularly adaptable for gas fired equipment using the conversion burner principle. Also, with slight changes, the Reynolds Low Pressure balanced valve regulator is adaptable for atmospheric and vacuum type regulation. For complete information concerning your gas control requirements write direct to Branch Offices, or Representatives.

Right: REYNOLDS LOW Pressure Balanced Valve Regulator used on furnace.

Below: Cross-sectional view of Low Pressure Unit showing Balanced Valve Construction.

NRA MEMBER U.S. WE DO OUR PART

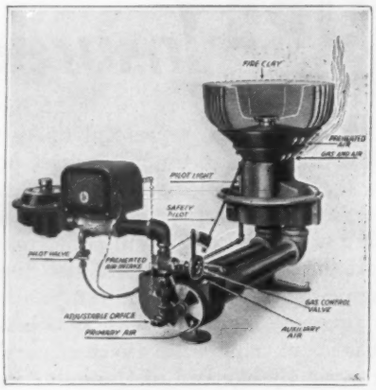
● **REYNOLDS BRANCH OFFICES:** 421 Dwight Building, Kansas City, Mo.; 2nd Unit, Sante Fe Building, Dallas, Tex.
● **REPRESENTATIVES:** Eastern Appliance Co., Boston, Mass. F. E. Newberry, Avon, New Jersey

REYNOLDS GAS REGULATOR COMPANY

Anderson, Indiana, U. S. A.

GAS CONTROL SINCE 1892

KILLAM PATENTED
***PRE-HEATED* AIR BURNERS**



. . . . . GIVE MORE HEAT FOR EVERY CENTS WORTH OF GAS . . . . . .

Primary and auxiliary air is mixed with the gas before it reaches the combustion chamber.

The only gas burner made introducing air to the gas in four different stages, thereby enabling us to get all the heat units from the gas.

KILLAM SQUARE BURNERS
can be built up to fit any size fire box, sits on the grate bars and is very easily installed.

Write For Catalog

Killam Gas Burner Mfg. Co.
236 Broadway
Denver, Colorado

Natural Gas Industry Loses Valued Leader

AN outstanding leader is lost to the natural gas industry with the death of Henry C. Morris, president of the Dallas Gas Co. and a pioneer gas man in the Southwest. He was stricken following his return from a trip to Salt Lake City, Utah, and died at Baylor Hospital in Dallas on August 17 after an illness of two weeks.

Henry C. Morris

He was a director of the American Gas Association, former chairman of the Natural Gas Department, vice-chairman of the National Directing Committee of Executives of the Association.

Mr. Morris was known as one of the leading natural gas company men in the United States, for many years taking a prominent part in the development of the industry. His advice and counsel were sought by executives of many other companies throughout the country. He was responsible to a large measure for bringing to Dallas its present natural gas service, the change over from manufactured gas 23 years ago having been accomplished under his direction. Throughout later years he has given unremitting toil to perfecting this service, his work along this line resulting in the widespread use of gas in Dallas homes and industries.

The new 11-story Dallas Gas building, the largest building in the Southwest devoted exclusively to the natural gas industry, is largely a result of Mr. Morris' activities in making Dallas a center of the natural gas industry in the Southwest.

His activity in the natural gas business included not only the Dallas Gas Co. but took in the active direction of a far-flung system of gas companies from Juarez, Mexico, to the Pacific Northwest. His supervision included the operation of Guthrie Gas Service Co., Guthrie, Okla.; Texas Cities Gas Co., operating in Paris, Brenham, El Paso, Waco, and Galveston; the Fort Worth division of the Lone Star Gas Co.; Juarez Gas Co. in Mexico; Council Bluffs Gas Co. in Iowa; and the Northwest Cities Gas Co., which includes distribution systems in Walla Walla, Yakima, and Clarkston, Wash.; Astoria, Pendleton, and Eugene, Springfield, North Bend, and Marshfield, Ore., and Lewiston, Ida.

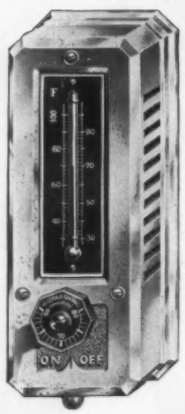
Mr. Morris was born in Detroit, Mich., and began his business career there working in a gas meter repair shop. In 1902 he became superintendent of construction for the Saginaw Gas Co. in Michigan, and 3 years later was made assistant manager of the Bay City Gas Co., Bay City, Mich. He came to Dallas in 1909 as superintendent of construction and operation for the Dallas Gas Co., and built the system up from 98 miles of pipe line and 8,743 meters to an extensive network of 765 miles of pipe line serving almost 70,000 meters.

In addition to his efforts in behalf of the utility, he took a keen interest in civic affairs. He was a director of the Dallas Bank and Trust Co., a director of the Dallas Chamber of Commerce, a member of Dallas Athletic Club, the Dallas Country Club, Pentagon Lodge A. F. and A. M. and Hella Temple Shrine, and Senior Warden and member of Diocesan Council of the Church of the Incranation and former treasurer of that church.

He is survived by his wife, three sons, two brothers and three sisters.

McCORKLE CONTROLS

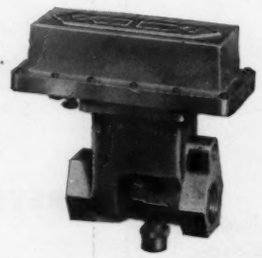
A new deal in THERMOSTATIC CONTROLS for Gas Fired Heating Equipment



GREATER RELIABILITY . . . ELIMINATION OF FLUTTERING . . . AUTOMATIC POWER - FAILURE SHUT - OFF . . . GREATER ACCURACY AND CLOSER REGULATION . . . A POSITIVE CLOSING ACTION TO ELIMINATE *STUCK* VALVES.

These and other qualities are made possible in the McCORKLE CONTROL by the development of a radically new application of a time tested principle.

A new simplified Standard Control Set, is now available at a price that will make its use on floor furnaces and space heaters, as well as competitive central heating installations, economically feasible.



Write Today for Prices and Information on Dealer and Jobber Representation

McCORKLE CONTROLS, INC.
Sixth and Bancroft Way
Berkeley, California

Plan Line to Tie Kansas Field With Texas-Minnesota Line

Northern Natural Gas Co. and Northern Gas and Pipe Line Co., Omaha, are reported to be planning construction of a 40-mile line from gas fields near Otis, Kan., to a point near Bushton, Kan., and erection of a booster station near Bushton. The extension from the Otis field will connect with the company's main line running north from Texas through Kansas to points in Iowa and Minnesota.

The Otis field now has a total open flow of 182,000,000 cubic feet daily.

The Spiragraph

(Continued from Page 76)

Multiply the 24 hourly extensions by the coefficient to obtain hourly gas flows.

Write the 24 hourly flows *on the calculation sheet.*

Add the hourly flows to obtain daily flow. Write daily flow *on calculation sheet.*

There are, of course, many abbreviations of the above method where extreme accuracy is not required. For example, if the static pressure is fairly uniform and L-10 charts are used, the static height may be approximated for the 24-hours and this multiplied into the coefficient. The hourly differential height readings may then be added directly on a comptometer without use of a calculation sheet. This sum, when multiplied by the pressure-coefficient product, gives the 24-hour flow.

In this latter case, the spiragraph shows no saving of time, for, though the two multiplications are not required, the spiragraph slows up the clerk in reading the differential heights. This results in a "breaking even" with neither method having the advantage in time. But the spiragraph method requires less effort and introduces less opportunity for mistakes.

As to precision, the spiragraph is as precise as the chart; that is, its numbered spirals are as precisely located on its face as are the numbered circles of the chart located on the face of the chart. With or without the spiragraph, accuracy is primarily a matter of the man's ability to "read" the heights of the chart pen lines and to write these down as read without careless transposition or other error.

Elaborate comparisons of spiragraph findings with extension book and calculating machine findings have shown that the two methods give exactly the same results except for a small give-and-take discrepancy that is always traceable to the human element. The spiragraph consistently has shown the advantage in accuracy due to the lesser number of operations, giving the man less opportunity for mistakes. The spiragraph's one reading is safer than the ordinary two readings. The spiragraph accomplishes its two multiplications and one root extraction without special acts to this end. The lack of need for a calculation form with its hundreds of written figures eliminates hundreds of opportunities for mistakes.

The spiragraph is the property of the Los Angeles Gas and Electric Corp., and was designed and developed by H. E. Thompson, power plant combustion engineer, and mathematician for the company. It is being used regularly for charts that must be calculated with accuracy; for charts that may be approximated, the company does not employ the spiragraph.

The device may at some future time be available to the public, but is not available at the present time, except that any corporation interested in rapid and accurate measurement of gas may arrange to borrow a spiragraph for experimental purposes. Inquiries to this end may be addressed to Los Angeles

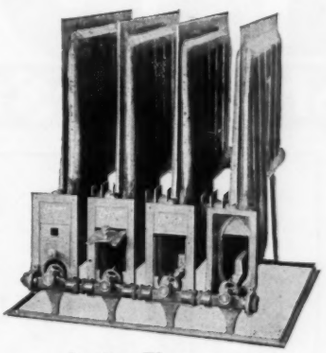
ANNOUNCEMENT

To meet the Growing demand for a Furnace that will give maximum economy at a minimum cost, we present, in addition to our complete line of FLOOR AND BASEMENT furnaces

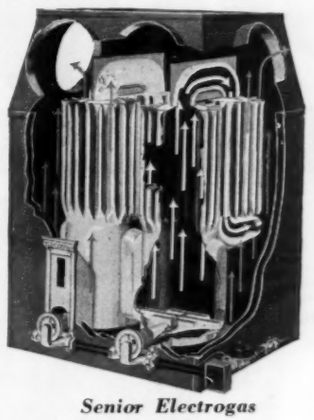
The New Junior Electrogas

BASEMENT FURNACE

Not an experiment; **It has taken four years of designing, laboratory and field tests to bring this perfection.**



Junior Electrogas



Senior Electrogas

***Now in Complete Production*—ready for immediate delivery.**

Write for sales portfolio and attractive dealer program.

ELECTROGAS FURNACE & MFG. CO.

4575 Bayshore Blvd., San Francisco **164 South Central Ave., Los Angeles**

The Goodman Stopper

The Reliable Shut-off for Street Mains

Equipped with Improved Patented Locking Sleeve, which locks both handles to the pipe. Stopper cannot slip. Gas cannot pass.

Safety Gas Main Stopper Co.
523 Atlantic Avenue, Brooklyn, N. Y.

Pac. Coast Rep.: C. B. Babcock Co.
135 Bluxome Street
San Francisco, California

AT LAST...

A Self-Regulating Pilot!

● After exhaustive research POWERSTAT announces ***Pilotrol***, a new device that automatically adjusts itself to pressure fluctuations. It delivers a uniform flame regardless of pressure and brings new dependability to gas appliances.

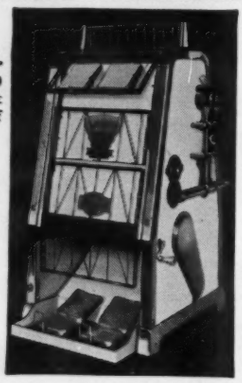
Pilotrol is simple and inexpensive. Made for various capacities. Easily applied to new and old equipment.

●*Trial order shipped on approval. Price, $1.00 each, $7.20 per dozen. Specify capacity.*

POWERSTAT CORPORATION
ARTHUR F. ERICKSON, PRESIDENT
557 Market Street San Francisco

PILOTROL
A Product of PowerStat

SAVORY MODEL P.D. makes as many as 360 slices of perfect Toast per hour at a cost of only ¾c. to 3¼c.



It makes BETTER TOAST

THE SAVORY radiant gas Toaster makes better profits, too—a sales profit and a fuel-profit. It is one gas appliance which saves money for its owner with every cubic foot of gas it burns. It is no wonder, then, that hundreds of institutions, restaurants, drug-chains and lunch-rooms are installing this fully automatic toaster. Write for full particulars to Savory, Inc., Dept. WG-9, 591 Ferry Street, Newark, N. J.

SAVORY
radiant gas
TOASTERS

PEERLESS Hearth-Fyres

Are available in many attractive designs

If you want real values to offer your customers, get the Peerless Catalog and make your selections early.

Peerless Manufacturing Corp.

Louisville :: Kentucky

Gas and Electric Corp., attention H. E. Thompson, combustion engineer, and should enclose blank charts identical to those on which the experiments will be made.

Personnel Changes in Minnesota Presage Line Construction

SEVERAL changes in the personnel of Minnesota Northern Natural Gas Co. have been announced during August by F. H. Brooks, president of Northern Gas and Pipe Line Co. of Omaha, Neb., parent organization of Minnesota Northern.

A. A. Hicks has been named district manager, with headquarters at Rochester, taking the place of Frank W. Budd, who has been transferred to the engineering and construction department, with headquarters for the present in Faribault, Minn.

Ralph W. Christie, sales manager, has been appointed field representative and will operate out of Owatonna.

Hermann Briese will continue as superintendent of operations, with headquarters at Rochester.

Plans for construction operations in the district are developing, with definite announcements looked for immediately. Tentative plans call for extension of the Northern Gas and Pipe Line Co.'s main line from a point north of Owatonna to Faribault, where the company has signed contracts to supply public institutions with natural gas for winter consumption. Northern States Power serves the dometsic market in Faribault.

On August 11 the company opened a new district office in Owatonna, placing Larry Shoemaker in charge. The Owatonna office will be headquarters for operations in Wells, New Richland, Alden, Dodge Center, Claremont, Kasson, Mantorville and Byron.

Mueller Co. to Establish Factory at Los Angeles

THE Mueller Company of Decatur, Ill., manufacturer of equipment for the gas industry during the past 76 years, will build a Pacific Coast factory in Los Angeles, construction to be completed to begin production by the first of the year. The new plant will manufacture valves, tapping machines, stop cocks, meter connections and meter hangers, for distribution in the 11 Western states and Pacific ports.

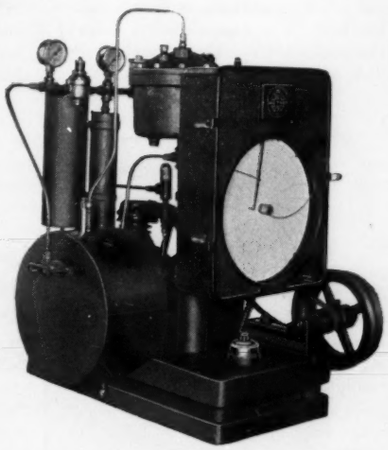
W. N. Dill has been appointed general manager of the Pacific Coast factory. Mr. Dill was with the Mueller Co. for 30 years, having severed his connections a few years ago and has rejoined the organization, effective July 1.

Tom Leary and Bill Jett, well known to the gas industry of the West will continue with the organization, Mr. Leary in charge of the San Francisco office and Mr. Jett in charge of sales out of the Los Angeles office.

Cost of the new plant will be in excess of $200,000, the site having been purchased at 2801 East 12th St. The building will be a one-story factory, covering 150 x 190 square feet. Contract has been let to the Austin Securities Co. for construction of the plant.

Metric Gravitometer Featured in American Meter Co. Brochure

Bulletin E-21 of the American Meter Co. Inc. describing the new Metric Gravitometer was brought from the press recently. The new device determines the specific gravity of a gas by measuring and recording the differential or the centrifugal force produced by a fan rotated in the gas at constant speed by an electric motor. It automatically eliminates the effect of variations in atmospheric pressure and temperature and gives a correct record of the specific gravity of the gas.



The booklet is well illustrated with photographs and descriptive drawings of the Metric Gravitometer.

D. C. Green Named President of Middle West Utilities, Chicago

Announcement has been made from the general offices of the company in Chicago that D. C. Green has been appointed president of the Middle West Utilities Co., succeeding Grover C. Naff, president of Wisconsin Power & Light Co., who has been on leave of absence from that company, returning there on the appointment of Mr. Green.

M. Green is nationally known in the gas industry and has been vice-president of Electric Bond and Share Co. for the past four years.

Peoples Gas & Power Co. Looks for "Natural" for Winter Load

Peoples Gas & Power Co., Chariton, Iowa, plans to change over its water-gas system to natural gas this fall on completion of a 24-mile line from Natural Gas Pipe Line Co. of America's main 24-inch line. Cost of reconditioning the distribution system and connecting lines will be approximately $75,000.

$3,000 Tax on Utilities Operating in Casper, Wyo.

Ordinances levying a $3,000 license tax on each of the public utilities operating in Casper, Wyo., were passed in July by the city council. New York Oil Co., operating the gas system is affected by the new ordinance.

A CENTURY of PROGRESS

—The Age of Gas—

WITHIN the span of the century Chicago is now celebrating, we have come from crawling over the earth in ox-carts to flying through the air, a development that symbolizes the era.

Gas was the first big development in this Century of Progress. The first gas company started in London, England, in 1807. Gas lighted the way, and while the heat element in gas is now admittedly its most useful feature, it is still a fundamental requirement in the lighting business; manufacturers of electrical equipment are among the largest users of gas for the fabrication of their products.

In fact, gas enters into the manufacture of everything we use or wear, from shoes to hats, from motor cars to baby carriages. This Century of Progress might as reasonably be called "The Age of Gas" as "The Age" of anything else.

THE PEOPLES GAS LIGHT AND COKE COMPANY

—CHICAGO—

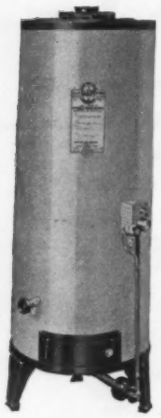
If you would keep in touch with the Natural Gas and Butane industries, send a check for $2.00 to

WESTERN GAS
810 South Spring Street, Los Angeles

Name.....
Company.....
Position Occupied.....
Street Address.....
City and State.....

Subscription Rates: I Year $2.00; 3 years $5.00; Foreign $3.00 per year.

HIGH QUALITY—LOW PRICE



AGP

AUTOMATIC STORAGE GAS WATER HEATERS

Three models of quality water heaters at a price range to meet any campaign requirement. Each combines the highest efficiency with improved principles of design and sturdy construction. Perfectly controlled, highly efficient, yet lowest in price for comparable quality.

A. G. P. made in galvanized or Everdur tanks—20-25-30-40-75 gallon sizes.

A. G. P. SPECIAL made in galvanized tanks—20-25-30-40-75 gallon sizes.

THE DICTATOR Low-Priced Water Heater is made in galvanized or Everdur tanks—15-20-30-40 gallon sizes.

Write for Literature!

AMERICAN GAS PRODUCTS CORPORATION

40 West 40th St., New York, N. Y.

Division of

AMERICAN RADIATOR COMPANY

For ECONOMY

HOTEL

SEELBACH

Every fine hotel advantage at low cost

SAMPLE ROOMS

In the heart of Louisville $3.50 $4. *and* $5.

500 Beautiful Airy Rooms—

Single $1.50, Double $2.50 without Bath

Single $2.00, Double $3.00 with Bath

WALNUT at 4th ST.

LOUISVILLE

Keeping the Lead in

MILWAUKEE, WIS.

RADIO

IN YOUR ROOM

WITHOUT CHARGE

Completing our $200,000 Modernization Program

Famous Food in the Coffee Shop

BREAKFAST....25¢

LUNCHEON.....35¢

DINNER..65¢ *Upward*

ALL ROOMS WITH BATH AND RADIO $2. UP

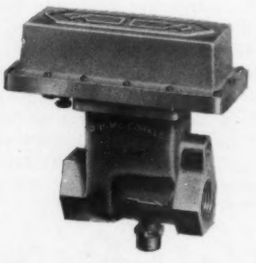
PLANKINTON HOTEL

McCorkle Controls Announces New Low-priced Thermostat

ANNOUNCEMENT has been made by McCorkle Controls Inc. of a new simplified thermostatic control. D. H. McCorkle, the inventor of the device bearing his name, was for many years owner of the Hall Furnace Co. of Oakland, until his company was absorbed in a consolidation. Several hundred controls have been installed over a peri-

od of the last 2½ years for field test and observation. The results of this experience led to the formation of a corporation with headquarters in Berkeley, Calif., with A. J. Horn, vice-president and general manager, and Mr. McCorkle spending his time in production and development work.

The control eliminates all use of solenoids in the valve. Instead, the motive power is



supplied by two heavy bi-metal blades between which is mounted an electrical resistor. Features claimed for the valve include an automatic power-failure cut-off and a design that eliminates any possibility of the valve "fluttering" or sticking "open." According to the manufacturers, the thermostat is capable of operating on a differential of less than 1° F., the resultant frequency of cycles being particularly important on conversion burner installations in that the circulation is not impaired by the furnace and pipes cooling too much between cycles.

McCorkle Control Sets are available with a choice of a de luxe or Master Series thermostat or a simplified and lower priced Standard Series thermostat, both made in a variety of colors and finishes.

Omaha Utilities Dept. to Spend $978,000 on New Gas Equipment

Improvement to the gas manufacturing plant and distribution system of the Metropolitan Utilities District in Omaha, Neb., calls for an expenditure of $978,000 of which the city is asking for a 30 per cent loan from the government for labor and materials.

Plans are reported to include a new gas holder to cost $70,000 boiler $35,000 oil storage tanks $30,000; purifiers, $50,000; station meter and building, $12,000; 16-inch gas line $111,000.

Metropolitan Utilities District is negotiating with Northern Gas and Pipe Line Co. of Omaha, for a supply of natural gas for enrichment of the water gas now being served.

Powerstat Brings Out New Self-Adjusting Pilot Light

Powerstat Corp. of San Francisco has announced a self-adjusting pilot light, called "Pilotrol." The new device is hardly larger than a thimble and, according to the manufacturers, will deliver through its adjustable orifice a desired uniform volume of gas, whether the gas pressure drops to one ounce or raises to a pound or more. The "Pilotrol" contains neither spring nor diaphragm and is claimed to be impervious to rust corrosion and acids.

Arthur F. Erickson is president of the Powerstat Corp.

Medicine Bow, Wyo. Scheduled for Natural Gas Service

Medicine Bow, Wyo., a typical cowpuncher town of pioneer days, will soon have natural gas service, on completion of a transmission line from the Allen Lake district, about 5 miles distant. Rocky Mountain Gas Co. of Casper, Wyo., has obtained permission to build the line and construct a distribution system.

Lincoln, Neb., State Institutions To Use Gas as Fuel

Gas conversion equipment for the state institutions of Lincoln, Neb., will cost in the neighborhood of $17,000, according to an estimate given to the board by the Iowa-Nebraska Light and Power Co. Contracts call for the company to supply gas at 24 cents per M for the first 1,000 M.

Central Illinois Natural Gas Co. Applies for Morton Permit

The Central Illinois Natural Gas Co., Elmwood, Ill., L. H. Waibel, general manager, has asked for a franchise to serve natural gas in Morton, Ill., in addition to the towns named in a previous franchise application.

Asks Permit to Operate in Oklahoma

Stonewall Gas Co. has been incorporated at Ada, Okla., and has asked the state corporation commission for permission to operate in the state of Oklahoma.

Johnson Conversion Burner
A Perfected Unit

In the Perfected Johnson Conversion Burner which we now offer, we have retained the basic features of the original famous Johnson Gas Heating unit—plus many refinements.

More efficient—more economical—a greater value in every way. Write for complete details.

JOHNSON GAS APPLIANCE CO.
Cedar Rapids IOWA
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ODORIZERS
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300 Car Fireproof Garage in Connection Serves all 3 Hotels

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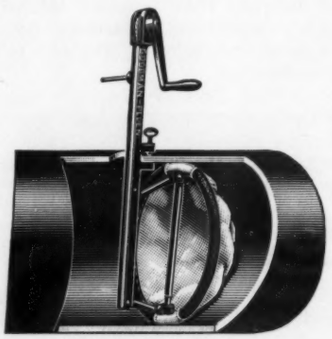
at Rock Island Illinois

SOUTH BEND
INDIANA

Goodman-Peden Stopper Safety Gas Main Stopper Co.

SAFETY Gas Main Stopper Co., Brooklyn, New York, maker of gas main stoppers since 1897 is introducing the Goodman-Peden Stopper designed by Hugh L. Peden, superintendent of mains of the Consolidated Gas Co. of New York.



In this stopper the flexible frame, padding, covering and diaphragm of the Goodman Stopper remain in principle but the handles have been discarded and in their stead a new arrangement in construction makes it possible to operate the stopper mechanically.

Descriptive literature is now ready and will be sent on request to the Safety Gas Main Stopper Co. at the above address.

Line Again Reported Scheduled for Texas-Mexico Service

Reports have again become current of plans to construct a natural gas transmission line from gas fields in the border region of Texas to Mexico City and intermediate points, with Electric Bond and Share Co. and its subsidiary the United Gas Co. as the interested companies. The route of the line calls for paralleling the present line from Zapata County, Texas, to Monterrey, Mexico, and extending it on south via Saltillo, San Luis Potosi, Queretaro and a number of smaller towns. It is reported that the Mexican government plans to help finance the project.

Gas Company Leases Sales Floor to Appliance Dealer

The Lexington Gas Appliance Co. Inc. has taken over the gas appliance display floor of the Frankfort Natural Gas Co. of Frankfort, Ky., and has placed Theo. Slade in charge of sales.

Mobile Gas Service Corp. is Successor to Mobile Gas Co.

Mobile Gas Service Corp., Mobile, Ala., has been organized as the successor to Mobile Gas Co. through a reorganization of the company's financial structure.

To Vote on Gas Bond Issue

A vote is to be called immediately at Columbus, Kan., on a bond issue for financing the construction of a municipal gas plant and distribution system. The town is now served by the American Gas Co.

Commonwealth Gas Corp. Succeeds Appalachian Gas Corp.

Commonwealth Gas Corp. has emerged from the reorganization of the Appalachian Gas Corp. and will manage all former subsidiaries of Appalachian, according to plans made at the reorganization meeting held early in August in New York. J. J. Klise of Wooster, Ohio, is president of the new holding company.

Among other companies, the new holding unit will control Memphis Natural Gas Co., Memphis, Tenn., and West Texas Gas Co., Del Rio, Texas.

Milton S. Binswanger has been elected president of Memphis Natural, and executive offices have been moved to Memphis. D. C. Shaffer is now executive vice-president, being advanced to that position from that of vice-president and general manager.

Saginaw Changed to Mixed Gas Service by Consumers Power Co.

Saginaw, Michigan, a city of 80,000 population was added to the list of natural gas consuming cities recently, when Consumers Power Co. began mixed gas service there, changing over from manufactured gas. A 50-mile, 8-inch line extends from the Broomfield gas field to Saginaw.

When the 157-mile line from Central Michigan field to Bay City, Flint, Saginaw and Pontiac is completed straight natural gas will be served in Saginaw, instead of the mixed gas.

Michigan Natural Gas Corp., has been granted a permit for construction of the line which will cost approximately $3,000,000, to be constructed of 20-, 12-, and 8-inch pipe.

Guy R. Kendall Appointed Electrogas Representative

Guy R. Kendall, for 12 years associated in gas appliance business in Los Angeles, has been appointed Electrogas Furnace and Manufacturing Co., representative for Southern California and Arizona.

He formerly was associated with the Portland Gas & Coke Co. Mr. Kendall maintains his office and display rooms at 164 South Central Ave., Los Angeles.

Getting Ready for Reconditioning Work at Richmond, Ky.

Black and Veatch, engineering firm of Kansas City, Mo., is preparing plans and specifications for the reconstruction of the municipal gas plant and distribution system at Richmond, Ky., the work to cost about $40,000. The necessary funds will be obtained through sale of gas revenue bonds to the Reconstruction Finance Corp. J. W. Hamilton is president of the Richmond Board of Water Works Commissioners.

F. W. Carter Now President of Peerless Manufacturing Co.

F. W. Carter has been appointed president of the Peerless Manufacturing Corp., Inc., Louisville, Ky. Mr. Carter is responsible for bringing out two of the company's radiant gas heaters—numbers 6255 and 6320.

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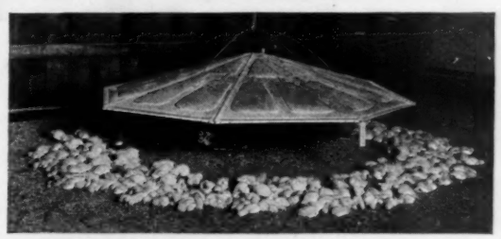
The new type Hart Radiant Gas Brooders are causing a sensation amongst poultrymen. They are proving by far the best means of brooding chicks. Increase your sales of gas by handling this leading line. Hart Gas Brooders will raise a greater percentage of chicks with less labor and expense than any other method. All brooders thermostatically controlled—hang from ceiling—teach chicks to perch—gas pipe runs overhead with flexible gas tubing running to brooder. Get your share of the vast potential fuel load for brooding of chicks and turkeys. One poultryman is worth a dozen ordinary household gas consumers.

Send at once for descriptive literature, discounts, etc.



Flashlight photograph of chicks sleeping under a Hart Gas Brooder at the world's largest poultry ranch where Hart Brooders are used exclusively. One hundred and forty-four brooders in operation the year round brooding five hundred to one thousand chicks to the brooder.

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GAS pressures of 50 to 100 pounds or more in tanks or transmission lines are reduced to medium or low pressure in the distribution system by the Fulton Toggled Reducing Regulator. It can be equipped to operate with either natural or manufactured gas, maintaining the desired delivery pressure with very little variation. For reversing furnaces, constructed with oversize valves. Also adapted for control of By-Product Coke Oven Gas. Ask for circular, No. 2573.

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Fulton Toggled Reducing Regulator

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Excels for Gas Service

The unusual care given to accuracy of diameter and welding qualities, makes Chester Pipe a favorite for gas lines.

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Inspection reports after years of actual service are true guides in judging rust preventive materials. Consider these:

Dearborn Representative, I. L. Yetman, reports: "Inspected 6 inch gas line coated with NO-OX-ID 'A Special' and NO-OX-ID-IZED Wrapper seven years ago. Inspected four places. The Wrapper and NO-OX-ID were intact and the pipe was in perfect condition. This is hard clay soil."

Dearborn Representative, W. N. Malcolm, reports: "Was informed today that line laid in 1929 was inspected by Mr. F——, Chief Engineer, recently and found in very good shape—the coating of NO-OX-ID 'A Special' still intact."

* * * *

These reports mark inspection periods only —not completed service. On thousands of miles of buried lines NO-OX-ID is standing vigil against rust. Reliable, long-time service, plus ease of application and reasonable cost. Data and estimates supplied gladly.

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Meter repairman desires position. Twenty years experience in repair work, 15 years shop foreman. Good references. In reply address Box E-235, *Western Gas,* 810 South Spring St., Los Angeles, Calif.

Fitzpatrick Goes With Ohio Oil; Roberts Assumes Management Duties

L. Fitzpatrick, vice-president and general manager of Utah Gas and Coke Co., Ogden Gas Co. and Wasatch Gas Co., headquartered at Salt Lake City, has accepted a position with the Ohio Oil Co. of Findlay, Ohio. J. D. Roberts, operating vice-president of the company, has assumed Mr. Fitzpatrick's duties.

Mr. Roberts was with Lone Star Gas Co., Dallas, Texas, from 1919 through 1928. He was appointed to his position with the Utah properties since the formation of Western Public Service Co. and its subsidiaries at the time of constructing the natural gas line from Wyoming fields to Salt Lake City and environs.

Selas Co. to Manufacture Equipment for Industrial Heating Processes

The Selas Co. of Philadelphia, manufacturer of industrial gas heating equipment, has recently expanded its business to include the design and construction of special automatic machinery for all types of industrial heating processes.

P. R. Hoopes, well known consulting engineer, has been retained as technical consultant on this work and will co-operate with the Selas engineering staff in developing automatic equipment.

Montana Power Gas Co. Now Operating Cut Bank-Butte Line

A subsidiary, the Montana Power Gas Co., has formally taken over the natural gas system of the Montana Power Co. constructed in 1931 at a cost of $7,500,000. The property transferred includes 20 gas wells, 22 gathering lines, 19 transmission lines and all personal property and equipment. The conveyance was filed on the last day of July.

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1. Anti-Ambi Recording Thermometer

A unique, fully compensated Thermometer. It produces accurate records of true line temperatures. These records are used to make accurate corrections that result in the elimination of costly errors caused by temperature changes during measurement.

2. Orifice Type Flow Meter

An economical instrument any way you look at it. Rugged—accurate—dependable—lowest in maintenance costs. This meter will stand the gaff of the roughest field service and give accurate readings under the most adverse conditions. Foxboro Meters should be specified wherever gas is valuable enough to require *accurate* measurement.

3. Time-Pressure Sensitizer

Losses from leakage are reduced to a minimum when the Time-Pressure Sensitizer is used. This instrument can vary the pressure to maintain the minimum for all varying load conditions. It can be equipped with aluminum cams that are easily cut and changed. This feature is a distinct advantage when schedules must be changed often during the year.

4. Differential Limit Controller

The most economical method of measuring wide ranges of flow is with a Foxboro Differential Limit Controller. This instrument is a combination of Foxboro Orifice Meters and a gas-operated control system. Installations have been made with these instruments which have had a wide range capacity of 200 to 1.

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You will find literally nothing like it elsewhere. Regardless of what you are now selling, it will be worth your time to investigate this outstanding development in gas heating.

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One of the jigsaw puzzles used in Denver summer sales campaign.

Colorado Utility Summer Sale Productive

SUMMER load-building on the Public Service Co. of Colorado system featured another of the contests which the company has found so productive. R. G. Munroe, gas new business manager, worked over the jig-saw puzzle idea for his purposes, preparing large puzzles, 3 feet by 5 feet for each of the three gas sales divisions—domestic, industrial and house heating. Individual pieces of the puzzles, representing predetermined amounts of sales accomplishment, were issued daily in line with sales results the preceding day, and the contest victory went to the division making the most progress on its puzzle.

The contest extended from June 15 to August 15, and was won by the house heating division, under F. M. Chelf. This division accomplished 120 per cent of its quota, with $8,970 sales against $7,300 quota. C. A. Bigler, superintendent of the domestic gas division, was second with 105 per cent of his quota sold, or $20,831 in sales against $19,800 quota. The quotas were set at twice the amounts of the departments' average sales per month for the first five months of 1933. In order to come into the contest prize awards at least 60 per cent of the quota had to be reached. Prizes for first and second places are trips to the American Gas Association Convention and the Century of Progress Exposition. According to Mr. Monroe, the contest was quite heated and created considerable excitement, a most noticeable feature being the keen interest on the part of the various gas sales representatives in the standings of their respective division heads.

Oil and gasoline coupons were given daily to each sales representative for each block of merchandise sold, which produced a puzzle piece for his chief. The pictures used for the three jig-saw puzzles were kept secret from the members of the gas sales department and superintendents. Each morning, during the regular 8:15 to 8:45 sales meetings held by each division, Mr. Munroe publicly awarded the puzzle pieces to which the division was entitled, along with oil and gasoline coupons to the territory representatives earning them on the preceding day. At the close of the meeting each sales division and its superintendent gathered around their puzzle and tried to fit the new pieces into the picture.

In accordance with the terms of the contest, F. M. Chelf, and C. A. Bigler, together with Mr. Munroe, will attend the A. G. A. Convention in Chicago as delegates representing the New Business Department of the Public Service Co. of Colorado.

Saanich, Oak Bay, and Esquimalt Now Being Served

New gas mains at Victoria, B. C., were placed in service recently by the gas department of the B. C. Electric Railway Co. to serve the municipalities of Saanich, Oak Bay, and Esquimalt for the first time. The new high pressure line will also give greater service facilities for some of the suburban sections of Victoria.

A. T. Goward, vice-president in charge of Vancouver Island operations, B. C. Electric Railway Co.; G. M. Tripp, general superintendent on Vancouver Island, and W. Dreaper, superintendent Victoria gas department, together with other company officials, took part in ceremonies inaugurating the new service.

"Ignition Arch" Plants Being Installed by Semet Solvay Engineering Corp.

Among the several plants in the South now being installed by Semet-Solvay Engineering Corp. of New York utilizing the ignition-arch process for carbureting water gas with heavy oil and gas oil, is the plant of the Savannah Gas Co., Savannah, Ga., where a 9-foot machine is being used.

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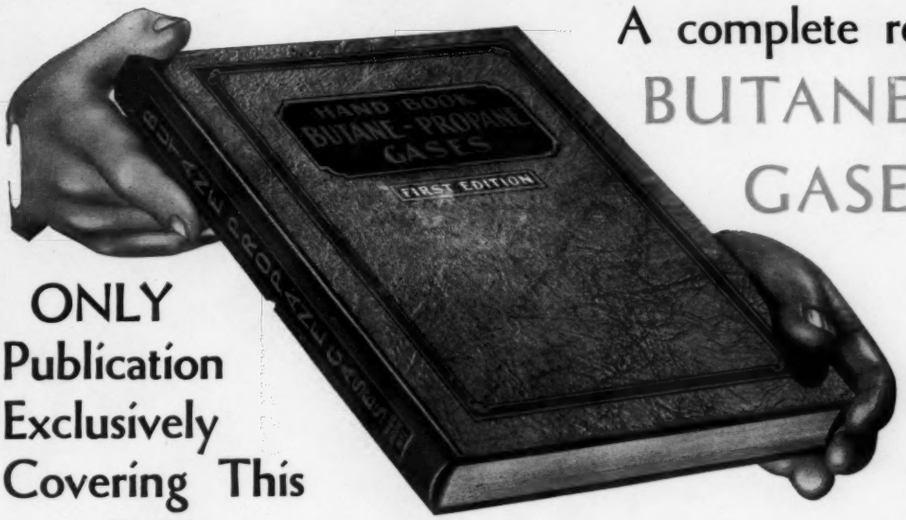
A complete reference work on BUTANE-PROPANE GASES —280 pages fully illustrated



ONLY Publication Exclusively Covering This Field

THIS Handbook comes in response to a very definite need. A tremendous amount of development work has been accomplished for the liquefied petroleum gas industry in a brief space of time, with many companies participating. And to date there has been no one source to which the industry could go for information on all phases of the field. This is the mission of the *Handbook of Butane-Propane Gases*—consolidating and organizing all of these reference data under one cover.

The editors have established close contact with all branches of the liquefied gas industry—production, bottled gas and town plant distribution, gas enrichment—and to assure a high standard of technical excellence for the Handbook leading figures in the industry have extended their cooperation as contributors.

In the next column contents of the *Handbook of Butane-Propane Gases* are reviewed. No phase of the field is neglected, and every major subject heading is treated in detail, making the Handbook an outstanding reference work. Numerous tables, charts and illustrations add to its value.

Orders for the Handbook have poured in from all sections of the United States, and from several foreign countries, since the first announcement of its compilation—indicating again the need for this publication and the growing interest in butane-propane service. A limited printing makes it imperative that you order now. Use the coupon below.

CONTENTS

A CHRONOLOGY OF LIQUID GAS DEVELOPMENT: Beginnings with Blaugas; first liquid natural gas sets; early industrial uses; expansion in domestic marketing; history of equipment; butane plant designs of early days. **PHYSICAL PROPERTIES OF THE LIQUEFIED PETROLEUM GASES:** Table of constants; discussion of general characteristics; vapor pressures; viscosity; specific gravities; combustion data; dew points of the pure gases carburetted with air; mean specific heats. **PROPERTIES OF BUTANE-PROPANE MIXTURES AND RELATION OF PROPERTIES TO TEMPERATURES:** Calculation of properties; calculation of vapor pressures; evaporation of mixtures; calculation of relative quantities evaporated; dew points of mixtures. **COMPOSITION AND ANALYTICAL DETERMINATION OF LIQUEFIED PETROLEUM GASES:** Specifications for commercial grades of propane and butanes; conventional gas analytical tests; low temperature fractionation analysis; description and operation of apparatus; calculations for liquid analysis; automatic operation; interpretation and computation on basis of low temperature fractionation analysis results. **THE MANUFACTURE OF LIQUEFIED PETROLEUM GAS:** Methods and processes in the natural gasoline industry; plant flow scheme for liquefied petroleum gas production; single column rectification; double column rectification with a finished gasoline from the primary unit; double column rectification with finished gasoline from secondary column; weathering; blending; handling from storage. **TRANSPORTATION OF LIQUEFIED PETROLEUM GASES:** Physical properties; grades of product; I.C.C. regulations; Reid method for vapor pressure determination; shipping in cylinders; tank car shipments; transportation by motor truck; pipe lines for butane; water transportation. **THE USE OF BUTANE AND PROPANE WITH MANUFACTURED GAS:** Calculations; enrichment of manufactured gas transmitted under high pressure; use of propane to meet peak loads; use of butane or propane as a substitute for gas oil for the carburetion of carburetted water gas; use of propane or butane for heating gas underfired coke ovens to reduce coke production. **CENTRAL PLANTS FOR BUTANE-AIR SERVICE:** The butane-air process; liquid storage; vaporization; carburetion; control; dehydration; odorization; gas storage; distribution; burner adjustment; conversion plants; representative flow sheets. **CENTRAL PLANTS FOR UNDILUTED BUTANE-PROPANE VAPOR SERVICE:** Field of usefulness of the undiluted vapor system; specifications for a suitable liquefied gas; estimating size and characteristics of the central plant load; design of gas plant; design of distribution system. **LIQUEFIED PETROLEUM GASES AS INDUSTRIAL FUELS:** Unloading and storage system; vaporizing system; mixing system; plant distribution system; atmospheric burners; low pressure combustion systems; diffusion combustion; typical applications; conversion problems, gas-fired equipment; conversion problems, liquid and solid fuel-fired equipment. **APPLIANCE UTILIZATION OF LIQUEFIED PETROLEUM GASES:** Combustion of propane, butane and commercial mixtures of these gases; burner orifice capacities; capacity of service pipe and house piping; general requirements for burners of all domestic appliances; gas ranges; space heaters; water heaters; lighting fixtures; draft diverters; cost of commercial propane compared with natural gas, manufactured gas and electricity. **BOTTLED GAS DISTRIBUTION OF LIQUEFIED PETROLEUM GASES:** The bottled gas field, present and future; equipment for bottled gas service; units engaged in distribution; economics of two-drum distribution; one-drum distribution; customer contracts; lease of equipment; selling through agents; sale by local agent; essentials in permanent market building; National Bottled Gas Association's tentative code of marketing practices; Underwriters' regulations relating to equipment and installations. **MISCELLANEOUS:** Table of flow of gas at low pressure through pipe lines; National Fire Protection Association's regulations pertaining to liquefied petroleum gas systems, other than those using portable containers. **CATALOGUE SECTION:** Detailed information on products designed for butane-propane service. **BUYERS' GUIDE:** A commodity listing of firms supplying equipment, appliances or services for the liquefied petroleum gas industry. **DIRECTORY OF CENTRAL PLANTS; BIBLIOGRAPHY; INDEX.**

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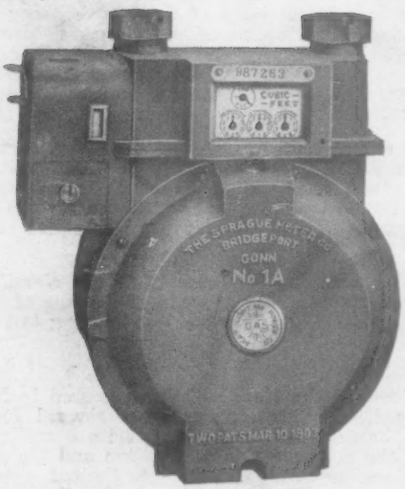

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